BRONCHOGRAPHY

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VAN GORCUM & COMP. LTD (G. A HAK & H J. PRAKKE), PUBLISHERS
ASSEN / NETHERLANDS

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PREFACE

This work has been made possible by the generous cooperation of a great number of co-workers We owe particular thanks to the radiologist Dr KEYSER, the surgeon Dr EERLAND, whose experience in thoracic surgery dates back to the years before the war, the internists Dr VAN BUCHEM and Dr ORIE, the paediatrician Dr VAN LOOKEREN CAMPAGNE, the pathologist Dr VOS, and their staffs The physiologist Dr DIRKEN was of great help to us A very large number of patients has been sent to us by the phthisiologists, staffs of chest clinics and sanatoria, and, particularly so, by the head of the Groningen Tuberculosis Centre, Dr VAN VLIET

For bronchography an accurate knowledge of the anatomy of the bronchial tree is indispensable For that reason, in Groningen considerable work on fresh lung specimens has been carried out for many years Respectfully we recollect the large amount of work performed with the assistance of the late pathologist Dr BEHR, who gave his life for our country in the last world war Later co-workers were Dr POTHOVEN and, particularly, Dr RAP

In the Groningen University Clinic several hundreds of bronchographies are being performed each year Thanks to that, considerable experience has been gained During the last few years we made an accurate study of the modern oblique projections These proved to be of great importance for the bilateral contrast examinations of the bronchial tree done at one sitting It was also possible to improve the bronchographic technique by introducing lipiodol fractionally

Due to the fact that the book on bronchography by Dr RAP and Dr SMELT, which was published in 1947, has met with great success and was sold out in a short time, the publishers VAN GORCUM AND COMP Ltd have asked us for a new and more extensive edition on the same subject, this time in the English language We readily agreed to this request, particularly so, because bronchography, a subject of the utmost importance, has never been discussed in a bookform in the English language In the book by Dr SICARD and Dr. FORESTIER on the use of lipiodol, an excellent chapter is dedicated to bronchography This work, however, written in 1927, is somewhat out of date, because since then considerable progress has been made in

pulmonary pathology and bronchography. We were of the opinion that there is need for a survey of the subject of bronchography as a whole. We gratefully acknowledge the splendid work done by VAN GORCUM AND COMP Ltd The reproduction of the large number of bronchograms was faithfully carried out. To Dr. C. O.'LEARY, superintendant of the Cork Sanatorium, Eire, who has corrected the English translation of the manuscript, we owe a great debt of gratitude.

There is at present time an awakening of the interest in the subjects of anatomy, physiology and pathology of the lungs. Bronchography is an important method for the study of the bronchial tree We do hope that this book will meet with the needs of various students of the subject, and may enjoy their favourable comments

Groningen, 1949.

Dr. E. H.
Dr. G. J. S

INTRODUCTION

It was a very short time after the work of SICARD, FORESTIER, LEROUX, SERGENT and COTTENOT appeared in press, that the radiologist KEYSER showed us some of these publications containing reproductions of lipiodol pictures. We soon agreed to his proposal that we should do it too. But it did seem at that time a risky undertaking to inject 20 to 30 cc of a treacly oil, the quantity then being used for a unilateral filling of the lung, into a person's wind-pipe. Not having had the authority to undertake such a responsibility on our own, we appealed for the help of a man who has always been *ready to lend a willing ear to new plans' i e the late internist* POLAK DANIËLS. But he was a very cautious man, and so it took some weeks before we were summoned to one of his patients. The recollection of this young woman still remains vivid: she daily expectorated an enormous quantity of fetid sputum. The lipiodol picture showed obvious bronchiectasis, and when on the next day the patient has asked us „When are you going to do the other side?", we were quite satisfied with the experiment. It was the first bronchography in the Netherlands, and at that time we certainly did not suspect that it would be the beginning of a large amount of work. However, it soon became obvious that there were many pitfalls. Particularly the interpretation of the bronchogram often met with great difficulties. Even the differentiation between normal and pathological often proved to be far from simple. Only very gradually, and through years of experience, was the accurate interpretation of bronchograms arrived at. The unceasing efforts of the radiologist KEYSER in producing better and better films, the improvement in the technique of introduction of lipiodol, and the splendid cooperation of many colleagues, are all factors responsible for the present standard of bronchography in our clinic. A teamwork resulted that, as we have been tought by our English and American friends, is necessary for the diagnosis and the treatment of pulmonary diseases.

It is now evident that an accurate knowledge of the anatomy of the bronchial tree is the main requisite not only for the proper technique of introducing lipiodol, but also for the interpretation of the various bronchograms. It took several decades and the efforts of many

investigators, beginning with AEBY, to arrive at our modern knowledge of the bronchial tree During the last few years a considerable number of excellent publications on this subject appeared, particularly from the U.S.A , England and France. A great number of schemes of the bronchial tree now exists. In Groningen this subject was also studied, particularly and lastly by RAP. On the basis of his very accurate investigations, the latest schemes by FORSTER-CARTER, BROCK, and JACKSON and HUBER were mainly confirmed. Only on a few points some small modifications were made Our present knowledge is not to be considered the final word on the bronchial tree. Still we can hardly imagine that anything but details are left. The main points are now definitely established. We know the accurate course of the various segmental bronchi, and we are acquainted with the main anatomical variations The various nomenclatures still offer difficulties at the moment, and it is our sincere hope that the terminology recommended by the International Congress of Otolaryngology, held at London (England) in July 1949, will meet with universal approval

Chapter I treats with the anatomy of the bronchial tree and of the lung segments A survey of the most frequently encountered anatomical variations is also given in this chapter.

The picture of the bronchogram strongly varies with the phase of the respiration, a fact not yet well known in the literature. This was the reason for devoting the separate Chapter II to the physiology of the bronchial tree, in which only the main points of importance with regard to bronchography are discussed.

Chapter III contains general considerations on bronchography, and, also, a survey of the literature concerning its development. A considerable part of it is of only historical value.

The vivid interest in the anatomy of the bronchial tree is the result of the extensive development of pulmonary pathology during the last years Owing to this, bronchography as well as bronchoscopy have assumed enormous proportions It should be stated, however, that all other methods of examination of the lung have completely retained their value.

Owing to the large possibilities now offered by thoracic surgery, an accurate localization of the morbid process is in many cases a necessity. Localizations like upper, middle, or lower areas, frequently used in former days, do not serve the purpose anymore In certain pathological conditions a lesion in the right "lower area", may be situated in the upper lobe, and, inversely, the tissue of the lower lobe may reach as far as the top of the lung For the localization of a pulmonary lesion

bronchography is a more accurate method than planigraphy. The latter is particularly good for outlining cavities

For the establishment of diagnosis and indications for operation in various lesions of the lung, bronchography and bronchoscopy now often furnish the finishing touches. It certainly is in the interest of a correct diagnosis that both procedures should be carried out by one man In many cases a, socalled, directed bronchoscopy, i e a bronchoscopy guided by the findings at bronchography, is of the utmost importance. Often, this is the only possible way to arrive at an exact diagnosis

The bronchoscopist must have an accurate stereoscopic idea of the anatomy of the bronchial tree, and, therefore, he is the obvious man to recognize the various segmental bronchi on the roentgenograms and to judge their situation in space Because of this, bronchographic examinations in the Groningen clinic have for many years exclusively been performed by the laryngologist

Great changes have taken place in the course of years, one should consider e g an affection like bronchiectasis, for which bronchography is of particular importance At first it was considered satisfactory if the bronchogram showed the existence of dilatation of the bronchi, at most it was noticed in which lobes the affection was localized Because of the possibility of segmental pulmonary resections, it is nowadays necessary to fill all the branches on either side A series of X-rays should be taken in various positions in order to get the correct impression of the extent and the localization of the diseased bronchi Therefore, after the discussion of the roentgen anatomy of the normal bronchogram in Chapter IV, Chapter V deals with the interpretation of the bronchogram, and describes the way in which serial bronchograms should be read

Chapter VI is devoted to the pathological bronchogram In this chapter we could have systematically discussed all affections for which bronchography is indicated, in each case describing the anomalies found on the bronchogram Experience teaches, however, that the bronchograms of different affections are very similar, so that we would have frequently repeated ourselves Anybody experienced in bronchography knows that in the pathological bronchogram a few possibilities only are in question the dilatation or the cavity, the stenosis or the stop, and the displacements It seemed to us to be preferable, considering the intent of giving a survey of bronchography, to take these anomalies of the bronchogram as a starting-point for our discussions The differential diagnosis of the various affections is, of course, also paid attention to

In Chapter VII the technique of bronchography in the Groningen University Clinic is described. Because of the large number of patients, some hundreds each year, the need of standardization of the technique made itself felt. It appears that with simple means very satisfactory results can be obtained, and for this reason a detailed account is given of our method. Great advantages are offered by the bilateral filling at one sitting, at which the oblique views play an important part. The latter are paid particular attention to in this monograph. In certain cases the use of MÉTRAS' sounds is of great value. These are now regularly employed by us, and their use is also described in detail in chapter VII.

CHAPTER I

THE ANATOMY OF THE BRONCHIAL TREE AND OF THE LUNG SEGMENTS

History

The bronchial tree In 1880 AEBY published his work "Der Bronchialbaum der Saugethiere und des Menschen", which was to become a classic Over 20 years later NARATH, at the time professor of surgery at Utrecht, wrote in his comprehensive work on the same subject 'Mit AEBY beginnt eigentlich erst die Geschichte des Bronchialbaumes" These words perfectly epitomized the epoch-making comparative anatomical research of the Swiss anatomist From it originated many anatomical and embryological studies, which led to our present knowledge of the subject Prior to AEBY's publication the prevailing opinion was that the trachea bifurcated, one bronchus going to each lung, and that a similar bifurcation recurred many times further on in the lung This theory of the so-called *dichotomy* was not a fortunate foundation for the profound study of this subject AEBY's work, however, clearly demonstrating the incorrectness of the old view, stimulated many investigators to further study They confirmed his views in many respects but discovered some discrepancies on the grounds of embryology and comparative anatomy

According to AEBY the basic structure of the bronchial tree is the same in all mammals, although frequent variations may make its recognition difficult The main bronchus does not divide immediately, in the pulmonary hilus, into various ramifications, but may be traced through the whole lung as far as the deep sulcus between the diaphragm and the spine This bronchus, which runs from the bifurcation as far as the most posterior edge of the lung, becomes narrower and narrower as it reaches the periphery, giving off a number of side-branches He called this the "stem-bronchus" This conception was subsequently much criticized [1])

[1]) The term 'stem bronchus" is often misunderstood and as used at the Groningen clinic might be explained as follows

The trachea bifurcates into two main bronchi and of these the left divides into two branches the upper lobe bronchus and the lower lobe bronchus

The right main bronchus after giving off the upper lobe bronchus becomes

AEBY also discovered that the right main bronchus was wider than the left and that it descended more vertically from the trachea. These observations contrasted with the anatomical literature of those days. *In regard to the structure of the bronchial tree*, AEBY attached much importance to the so-called eparterial bronchus This is the bronchus for the right upper lobe, which branches off above the point where *the pulmonary artery crosses the stem-bronchus* All other bronchi branch off below this point and are therefore hyparterial The manner in which the pulmonary artery divides and subdivides is, in fact, very similar to that of the bronchial tree *On both sides the stem-*bronchus is crossed high up in front by the stem of the artery, which further down passes behind the stem-bronchus AEBY also pointed out that this intersection of the pulmonary artery and the stem-bronchus is present in all species of animals, and always at the top of the stem-bronchus.

The eparterial bronchus always occurs singly, and usually asymmetrically It plays a decisive part in the origin of the type pulmonale, as this eparterial system, which in a completely developed lung is present on both sides, may be lost on one or on both sides If it occurs on one side only, it is always the right side In a few minor investigations (WEBER, LEBOUCQ, AEBY) it was possible to ascertain that in cases of situs inversus the relations on the right and the left were exactly opposite, so the eparterial bronchus was on *the left side* in these cases

Thus three basic types originate, viz.:

1 *The bronchial tree with an eparterial system* on both sides
2 The bronchial tree with an eparterial system on the right side only (fig 1)
3 The bronchial tree without an eparterial system.

The first and the third basic types are therefore symmetrical, the second is asymmetrical

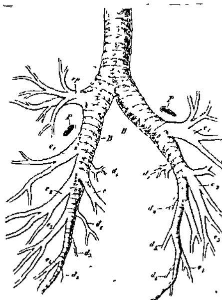
AEBY considered the bronchial tree with the bilateral eparterial bronchus as the original type from which all other forms developed as a result of the loss of certain side-branches This is the so-called *reduction-theory*, which at first seemed to be completely confirmed, especially by D'HARDIVILLER's investigations *The latter found in a* rabbit's embryo, at a certain stage of its development, a rudimentary

the stem bronchus The stem-bronchus divides into the middle lobe bronchus and the lower lobe bronchus

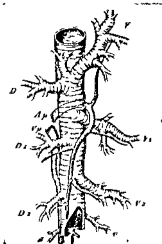
Thus the term stem-bronchus is reserved for that part of the right main bronchus lying between the upper lobe bronchus and the middle lobe bronchus

anlage of an eparterial bronchus on the left side. This formation disappeared during further development Later investigators, however, could not confirm this and it is possible that D'HARDIVILLER happened to investigate one of the anatomical variations that tend to occur in the bronchial tree The reduction-theory met with little support

Later it was assumed that the original type was the bilateral hyparterial one Owing to an extension in a cephalic direction unilateral and bilateral eparterial types were supposed to have originated This is called the *extension-theory*



1a The bronchial tree



1b The right bronchial tree
Lateral view

Fig 1 Pictures of the bronchial tree (Published by AEBY in 1880)

Fig 1 is a semi-diagrammatic representation of the human bronchial tree as AEBY conceived it, based on models made from metal casts The trachea and the stem-bronchi are shaded It is clearly indicated in the figure that the right stem-bronchus is wider than the left and lies more in line with the trachea This is very important from the clinical point of view

The eparterial bronchus (ep), which is absent on the left side, supplies the right upper lobe Below the intersection of the stem-bronchus and the pulmonary artery (P) lies the hyparterial system,

which is perfectly symmetrical and on both the right and left sides 4 ventral (v_1, v_2, v_3, v_4) and 4 dorsal ((d_1, d_2, d_3, d_4) branches can be seen The arrangement of these bronchi branching off singly from the stem-bronchus is therefore very regular in two rows. The dorsal and ventral branches alternate, and the more strongly developed ventral bronchi usually branch off at a slightly higher level than do the dorsal ones The first ventral bronchus supplies the middle lobe on the right side and the upper lobe on the left, all the remaining ventral and dorsal branches therefore supply the lower lobes. The cardiac bronchus (c) should morphologically be considered as belonging to v_1, as a so-called co-ordinate bronchus. Consequently in some species of animals it does not come off from the stem-bronchus as a separate branch, but has a common stem with the first ventral bronchus. This cardiac bronchus merits special attention because in many animals (e g monkeys) it supplies a separate pulmonary lobe lying behind the heart (lobus infracardiacus) On the left side a similar bronchus is occasionally found in a very few species of animals

According to AEBY knowledge of the development of the bronchial tree is essential if the division of the pulmonary lobes into three on the right and two on the left side is to be understood. The view that the right middle lobe arises from a division of the upper or the lower lobes then ceases to be tenable, because the right upper lobe belongs to the eparterial system, and as this is absent on the left side, it has no counterpart there The middle lobe on the right side should be considered as belonging to v_1 The left upper lobe is also supplied by this bronchus, and the right middle lobe should therefore be considered as a homologue of the left upper lobe. With the further differentiation of the side-bronchi in subsequent schemes, the conception of homology between the right middle lobe and the lower part of the left upper lobe (the so-called lingula) became more obvious.

AEBY, however, attached little importance to the division of the lung into different lobes As there are no anastomoses between parts of the lung supplied by different bronchi, he considered that the circumscription of the pulmonary lobes was without any significance The shape of the bronchial tree is primary and is not influenced by the origin of the pulmonary lobes.

NARATH's investigations confirmed AEBY's views in many respects, particularly in regard to the stem-bronchus He stated that AEBY himself had already stressed the fact that the broad structure of the human thorax prevents the difference between the stem-bronchus

and the side-bronchi from standing out more clearly, as the stem-bronchi are shorter, while the side-bronchi are markedly developed NARATH, however, absolutely denied that there was any importance in the relationship between the pulmonary artery and the bronchial tree According to him no fundamental difference exists between the eparterial and the hyparterial bronchi He considered that the eparterial bronchus is a dorsal bronchus, originally a lateral side-branch of the first ventral bronchus and moved higher up on the stem-bronchus

NARATH also differed in his opinions on various other points of importance He did not find that the course of the pulmonary artery in relation to the stem-bronchus was constant, a point to which AEBY had attached much importance His observations were that the artery does not cross the main bronchus at one definite point, but often winds around it in a spiral NARATH also drew attention to the fact that, as a rule, the pulmonary artery lies more on the lateral side of the stem-bronchus than on the dorsal side as AEBY had indicated

NARATH did not support the reduction-theory According to him only one row of side-branches, the ventral, originally came off from the stem-bronchus In his view the dorsal branches developed from these ventral bronchi by the displacement of lateral side-branches This conception of the possibility of displacement of certain side-branches is the so-called *migration-theory* This theory was first clearly formulated by WILLACH, but it was NARATH who vigorously upheld it

There is also a considerable diversity of opinion concerning the cardiac bronchus AEBY considered that this bronchus was a co-ordinate bronchus of the first ventral bronchus v_1 and demonstrated it on the right side only NARATH, however, thought its origin was in the second ventral bronchus and held the view that on the left side a side-branch of v_2 should be considered the homologous bronchus

HIS, on the other hand, was of opinion that this bronchus is an independent bronchus without a homologue He based his view mainly on the fact that, at an early embryonic stage, it can be recognized as an independent branch of the stem-bronchus The problem of the homologous branches on both sides has always excited much interest Communications about it continue to appear in the literature HUNTINGTON who has written excellent and very critical dissertations on the bronchial tree, based on his own investigations, always carefully indicates which bronchi on the right and the left should be considered homologous HUNTINGTON also limits the stem-bronchus much more closely than AEBY does He terminates it in the lower lobe, near the branching off of v_2, where often a bifurcation into two completely

equivalent branches takes place. In 1920 he published a detailed report in which he discussed the various theories Having considered various facts, he eventually propounded what he called the *selection-theory*. the primitive lung of the vertebrates adapts itself to circumstances as they differ for the various species of mammals, according to the shape of the thorax, the manner of locomotion, the surroundings, etc and from these further differentiation occurs

Many very different conceptions were gradually evolved by both embryologists and anatomists The investigations and dissertations of men like AEBY and NARATH brought the bronchial tree into too much prominence compared with the lung itself As a means of supply and removal, however, it is only secondary to and subject to the structure and the development of this organ. Earlier embryologists considered that the structure they found in the young embryo was the stem-bronchus, on which the various lateral-branches were *already recognizable In reality, however, they observed the anlage* of the whole lung, and it is possible to discern the different lobes at an early stage HEISS and others gave prominence to the view that the differentiation of the lung is not so much a result of the centrifugal sprouting of the epithelial anlage, a view still held by BENDER, as of a centripetal formation of different septa. This moot point is not yet completely solved Probably both factors' centrifugal outgrowth and centripetal ingrowth, will eventually be proved to play their parts

Completely new conceptions were brought forward by MARCUS He studied the development of the lung from a comparative anatomical point of view, from the simple air-pouch of the amphibians up to the intricate human organ *In doing so he found that when the need for* a greater area of respiratory surface arises, partitions develop in the lung. By means of a partial fusion of these partitions the bronchi are formed Two mechanical factors are of great importance in this process The air being inhaled must meet with as little resistance as possible and the lung must be able to expand equally well, without stretching its tissues too much To solve this twofold task the originally reticular arrangement of the partitions changes into a spiral form in reptiles and is found again and again in the structure of the bronchial tree of higher animals. The main bronchus of the hedge-hog e.g. forms a fine spiral As the lung expands or collapses this spiral becomes wider or narrower and supply follows the respiratory movements. Stereo-pictures of the human bronchial tree, taken by means of lipiodol, also clearly reveal this spiral course of the bronchi This theory, in contrast to AEBY'S, thus makes *the bronchial tree the product*

of the pulmonary tissue According to MARCUS the formation of lobes also depends on functional factors Originally the lungs are symmetrical and not divided If, however, due to a more intensive metabolism the want of a greater respiratory surface becomes imperative, the pulmonary lobes are formed This causes certain parts of the lung to take up different positions and to utilize the room available with the utmost efficiency This formation of lobes is not a simple procedure, however It is necessarily accompanied by extensive changes in the internal structure of the lung

MARCUS' very fine experiments were continued by HILBER, and he too arrived at the conclusion that the aerodynamic laws eventually determine the shape of the bronchial tree The type of ramification is determined by the way in which the air can be conveyed into (or removed from) a particular part of the lung with the minimum of resistance The spiral course of the bronchi would be complicated if e g the eparterial bronchus were to branch off hyparterially, so that an explanation of the presence of a hyparterial bronchus should be found in mechanical and anatomical conditions From the mechanical point of view the spiral shape should be maintained as much as possible, and the angle at which the side-bronchi branch off must give the maximum facility to the flow of air Anatomically, when the heart is centrally located, HILBER gives a satisfactory explanation of the presence of eparterial and hyparterial bronchi on either side Should however the heart be located in the left half of the thorax, as in man, it is only possible to have an eparterial bronchus on the right side because of the above mentioned factors

Even though many of AEBY's conceptions were eventually refuted, the great stimulating and historical value of his work should not be overlooked

The investigations of AEBY became widely known, thanks to the work of later investigators, but knowledge of EWART's investigations, on the other hand, remained almost entirely confined to Anglo-American literature. Extracts have frequently been quoted from his dissertation "The Bronchi and Pulmonary Vessels", published in 1889 This work should rate with AEBY's "Bronchialbaum" as one of the pillars of the anatomical knowledge of the bronchial ramifications Just as AEBY delineated certain parts of the lung around the supplying bronchus, EWART also concluded that "within each lung large groups of lobules are kept in practical isolation from each other as regards their air supply Each of these sublobar groups may be considered as forming separate respiratory districts" Here for the first time

the concept of "bronchopulmonary segment" found clear expression His theory of pulmonary structure consisting of isolated independent parts was considerably strengthened by his observation that the pulmonary artery also ramifies in the same way as does the bronchial tree The nomenclature originated by EWART differs very much from

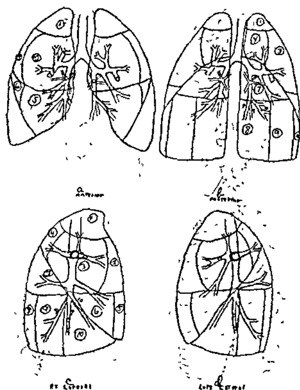


Fig 2 Scheme of KRAMER and GLASS (1932)
Upper lobe 1 apical, 2 anterior, 3 axillary, 4 paravertebral
Middle lobe 5 anterior, 6 axillary,
Lower lobe 7 apical, 8 paravertebral, 9 postero-lateral, 10 antero-lateral, 11 mesial

that of AEBY, who only used a few simple names and numbered the bronchi in the order in which they branch off from the stem-bronchus (eparterial bronchus, first ventral etc., first dorsal etc) In EWART's description every bronchus has its own name and nowadays this has become general usage

The work of the old masters AEBY, NARATH, HUNTINGTON and EWART was considered to be authoritive for many years and until

the nineteen twenties their views on the structure of the bronchial tree were never seriously questioned. The gradual development of new technical possibilities such as bronchography, endoscopy and thoracic surgery, however, renewed interest in this subject.

The development of bronchography in the twenties made it possible, for the first time, to visualize and study the bronchi in living human beings. This in particular cast some doubt on the correctness

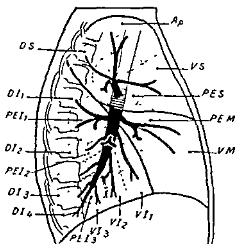


Fig. 3. Right lung. Lateral view. (LUCIEN and WEBER 1936)

Ap	= Zone apicale	DI 1	= Zone dorsale inférieure 1
DS	= „ dorsale supérieure	DI 2	= „ „ „ 2
VS	= „ ventrale supérieure	DI 3	= „ „ „ 3
PES	= „ parabronchique externe sup.	DI 4	= „ „ „ 4
PEM	= „ „ „ moyenne	VM	= „ ventrale moyenne
PEI 1	= „ „ „ inf. 1	VI 1	= „ ventrale inférieure 1
PEI 2	= „ „ „ inf. 2	VI 2	= „ „ „ 2
PEI 3	= „ „ „ inf. 3	VI 3	= „ „ „ 3

of the old conceptions. It was observed that there were some important discrepancies between the old conceptions and the pictures obtained on the bronchograms. In many places the investigation into the anatomy of the bronchial tree was taken up anew and various investigators have since tried to draw up new and more correct conceptions.

Thus various schemes came into being, e.g. a German one by HERRNHEISER (1936) fig. 6, a French one by LUCIEN and WEBER (1936) (fig. 3), and Anglo-Saxon ones by KRAMER and GLASS (1932)

(fig. 2), NELSON (1934) (fig 4), CHURCHILL and BELSEY (1939) (fig. 5), and FORSTER-CARTER (1943) (fig. 7) In the Netherlands too an

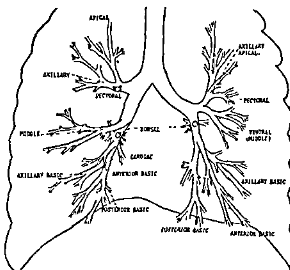


Fig 4 Bronchial tree (NELSON 1934)

extensive investigation was made by HUIZINGA and his co-workers BEHR and POTHOVEN (1938—1939 and 1942). All of these schemes differed considerably from each other on various points, and it were

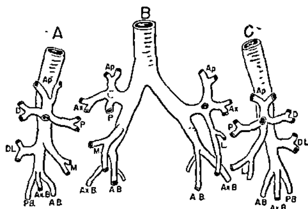


Fig. 5 Scheme of CHURCHILL and BELSEY (1939)
A right lateral B frontal. C left lateral. Ap = Apical Ax = Axillary P = Pectoral D = Dorsal L = Lingula M = Right middle lobe bronchus D L. = Dorsal lobe bronchus. A B = Anterior basic Ax B = Axillary basic P B = Posterior basic

these differences which stimulated further and still more detailed studies, resulting in our present knowledge of the anatomy of the bronchial tree.

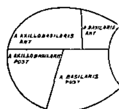


Fig 6a Right lung
Basal view

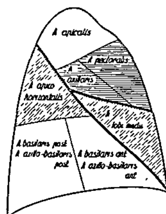


Fig 6b Right lung Lateral view

Fig 6 Scheme of HERRNHEISER (1936)

The most recent publications in this field are those of JACKSON and HUBER (fig 8), BROCK (1945) (fig 10), and RAP (1947) Serious differences

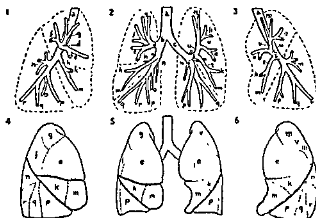


Fig 7

The bronchial tree and the corresponding lung segments Scheme of FORSTER-CARTER (1943)
1 4 right lateral 2 5 frontal. 3 6 left lateral.

a Trachea, b
lateral / Post
middle, n Do
upper bronch

Apical branches of the Apico-posterior bronchus.

of opinion on the structure of the bronchial tree no longer exist, and such differences as do exist are limited to unimportant details

Nevertheless the extensive anatomical investigations of the old masters such as AEBY, NARATH, EWART, HUNTINGTON and others have not been in vain. These old anatomical studies have been the basis and origin of many later investigations which led to our present accurate knowledge of the ramifications of the human bronchial tree, and which is so important in clinical work It may be asked what is the value of the still more extensive comparative anatomical investigations? We now know that there is no definite scheme from

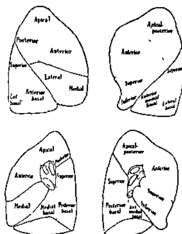


Fig 8 Scheme of JACKSON and HUBER

which all forms of the bronchial tree in the different mammals develop

The fetal tissue of the pulmonary lobule possesses the full potentiality of forming bronchi and pulmonary tissue. Under altered mechanical conditions, e g due to evolutional changes, it is quite possible that a bronchus may develop elsewhere in the bronchial tree At the same time comparative anatomy provides important data for clinical purposes, e g as an explanation of anatomical variations In humans too the bronchus of the right upper lobe sometimes branches off from the trachea, an observation which appears in a different light if one realizes that this is the normal state in many mammals The bronchus cardiacus on the right side bears even more significance if one is aware that many mammals have a separate cardiac lobe

As far as the structure of the bronchial tree is concerned, the

mechanical factor determined by the flow of air, while of great importance, is not the only factor concerned Side by side with it that mysterious power continues to exist, which causes the organ to form itself, as it were, from inside outwards It is striking indeed that the same structural scheme is always found, in spite of the differences in a particular species Tall and thin people have the same bronchial tree as those who are short and fat And finally the question of the homology of the right and the left sides, which used to be the subject of much work, arises Apart from a few differences a striking symmetry certainly exists between the right and the left lungs Thus a comparison of the two lungs reveals the marked similarity, from the anatomical point of view, of the middle lobe of the right and the lingula of the left, which are therefore considered homologues, a point of undoubted significance

The lung segments In addition to the anatomy of the bronchial tree, all investigators have paid considerable attention to the so-called lung segments The bronchi of the lobes of the right and the left lungs appeared to divide almost always, in each lobe, in a typical way into a constant number of lateral-branches and gradually the idea, earlier formulated by EWART, that these lateral-branches supply a definitely limited part of the lobe concerned, began to gain ground The lobes are always supplied by their own bronchus and it is logical that the further division of the various lobes was supposed to be in accordance with the way in which this bronchus ramifies. Parts of the lung supplied by a large branch of a lobar bronchus were given the name of lung segments This name, however, has no relation whatever to the fetal segment formation The appertaining bronchus, a bronchus of the 3rd order consequently, was called the segmental bronchus KRAMER and GLASS were among the first to give a satisfactory definition of the concept of "lung segment" We quote as follows "This unit, the bronchopulmonary segment, is a subdivision of a pulmonary lobe Each segment occupies a definite constant position in the pulmonary architecture and thoracic cavity and is supplied by a constantly placed bronchus, whose orifice is situated in a large lobar bronchus"

The limitation of such lung segments was all the more obvious because, according to many investigators (AEBY, EWART, HERRNHEISER, KUBAT) the pulmonary artery ramifies in exactly the same way as does the bronchial tree A particular part of the lung therefore, is supplied by one bronchus and also by one corresponding artery

HUIZINGA suggested that the structure of the pulmonary segment is generally wedge-shaped, the point being directed centrally, while the base lies on the surface of the lung and appears to be projected on the thoracic wall.

The lung segment can therefore be considered as a sort of unit. This holds good not only in anatomical and physiological respects, but also in pathological cases This has made the lung segment an important clinical concept, as certain pathological processes may remain within the limits of the segment, and leave other segments of the same lobe intact This segmental limitation of certain pulmonary lesions, such as bronchiectasis, atelectasis and in certain kinds of pneumonias, was explained by the assumption that the cause of the lesion is situated in one definite bronchus or artery, which supply this particular segment.

The basis of this original anatomical explanation was the supposition that the ventilation of a lung segment was only possible directly, by way of the appertaining segmental bronchus Investigations by VON ALLEN and later by BAARSMA, DIRKEN, and HUIZINGA have shown with certainty that considerable interchange of air is possible between neighbouring parts of the lung, supplied by different segmental bronchi, if certain differences in air pressure occur. BAARSMA called this *collateral ventilation*, and he showed it to be proportional to the degree of difference in pressure. This is only possible when a communication exists between the different parts of the lung, consisting of pulmonary parenchyma. For long the existence of alveolar pores has been a moot point As early as 1847 they were described by ADRIANI, but later investigators (SCHULTZ, KOLLIKER) denied their existence Others (MILLER) considered them to be the result of pathological processes BAARSMA and DIRKEN, however, succeeded in demonstrating them convincingly in rabbits' lungs which were fixed by means of a special technique, and there is every reason to assume that they also exist in man

In the Groningen clinic it was determined with certainty that collateral ventilation also exists in man and is very important. Further investigations showed that collateral ventilation cannot take place under certain circumstances This is the case when the respiration is superficial, when there is inflammation, and when congestion occurs in the pulmonary circulation Furthermore collateral ventilation is of course impossible between the various pulmonary lobes, and also when a lung segment is separated by a deep sulcus from the other segments of the lobe This occurs not infrequently, fig. 16 gives

a few fine examples The discovery of the collateral ventilation and its properties has considerably added to our views of pulmonary pathology.

The investigators, who since 1920 devoted themselves to the study of the anatomy of the bronchial tree, have drawn up various schemes of the circumscription of the pulmonary segments These schemes, however, like those of the anatomy of the bronchial tree, all show considerable differences The latest publications in this field came from FORSTER-CARTER, JACKSON and HUBER, and BROCK The last named, in particular, has carried out a very fine and extensive investigation. Excellent plates are to be found in the recently published scheme by SOULAS, derived chiefly from the works of JACKSON and HUBER It would lead us too far afield to discuss all these schemes individually, although it would be very interesting from a historical point of view Suffice it therefore to give a short enumeration of the most important differences among them They are chiefly as follows·

a The division of the bronchus of the right upper lobe The number of branches and segments ascribed to it varies between 2 and 4

b The supply of the axillary area in the upper lobes Some investigators think it is supplied by a direct laterally directed 4th branch of the upper lobe bronchus, as an independent segment.

c The division of the left upper lobe, which, according to the latest English investigations, contains 5 segments

d The division of the lingula Descriptions of its division into a lateral and a medial segment, and into an upper and a lower segment are found in literature

e The presence or absence of a 2nd ventral bronchus in the left lower lobe In English and American literature this branch is regularly described In the Dutch scheme, however, it occurs as a variation only

In 1947 these points were once again closely studied in the Groningen clinic by RAP, from very accurate autopsy of rich material Except for a few minor exceptions the schemes of JACKSON and HUBER and BROCK were confirmed.

Further RAP touched upon a very important point in his study, viz the nomenclature. He rightly pointed out the existing confusion in terminology and proposed to introduce an international nomenclature for the segmental bronchi and the appertaining segments Like RAP we take the point of view that the English-American nomenclature is generally preferable, as it has the great advantage that the

names of the segmental bronchi and the bronchopulmonary segments are similar. We shall return to the subject of establishing international nomenclature, after the discussion of the anatomy of the bronchial tree and of the lung segments



Fig 9a Right bronchial tree

Fig 9 Pictures of section preparations The lm
The segmental bronchi a

The anatomy of the bronchial tree

The trachea and the main bronchi The trachea is situated approximately in the median line, the lowest intrathoracic part, however, slightly deviates to the right. Posteriorly, where the cartilage is absent, it is slightly flattened The lumen has an almost constant diameter Only at the level of the thyroid gland and immediately above the bifurcation is the diameter of the lumen, when measured antero-posteriorly, slightly smaller. On the left side a small indentation, due to the aorta, is often visible. At the level of the fourth to sixth

thoracic vertebra (in children the fourth, in adults the sixth) the trachea bifurcates into the right and the left main bronchi These two are the so-called bronchi of the first order The angle at which the main bronchi lie to the median line may vary considerably



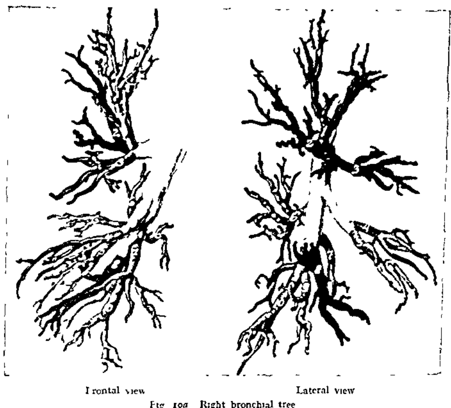
Fig 9b Left bronchial tree

of the bronchial tree has been cut open
bered (see fig 21)

The average angle amounts to 25° for the right side, and to 50° for the left side The right main bronchus descends more steeply and is also wider than the left, this is important for clinical purposes because this is why foreign bodies usually lodge in the right lung While on the right side the main bronchus usually runs slightly forwards, on the left the main bronchus deviates slightly backwards This is important for bronchoscopy and bronchography

The right main bronchus has a length of from 3,8 to 5 8 inch It then gives off from its lateral wall the large bronchus for the right

upper lobe The latter often branches off at a still higher level, so that the opening of its lumen is at the level of the bifurcation Rarely, however, its origin lies an inch or so lower. The right main bronchus continues, after giving off the bronchus for the upper lobe, as the



Frontal view Lateral view

Fig 10a Right bronchial tree

Fig 10 The bronchial tree These pict Anatomy of the bronchial tree The

so-called stem-bronchus From 1 to 1½ inch further on it gives off the bronchus for the right middle lobe in front and then passes into the bronchus of the right lower lobe

The left main bronchus is longer than the right. It divides, about 2 inches beyond its origin, into the upper lobe bronchus and the lower lobe bronchus The lower lobe bronchus forms the direct continuation of the left main bronchus The upper lobe bronchus does not branch off truly laterally, as is the case on the right side, but more antero-laterally. This peculiarity should be thoroughly taken into account in bronchography.

The bronchi for the different lobes of the right and left sides are the lobar bronchi, they are also referred to as bronchi of the second order. We shall discuss how these lobar bronchi divide in the various lobes into bronchi of the third order, the segmental bronchi.

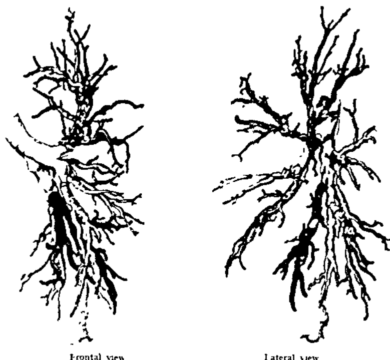


Fig 106 Left bronchial tree

...e been reproduced from BROCK R C
...ntal bronchi are numbered (see fig 21)

The right upper lobe The bronchus for the right upper lobe soon *divides into a number of branches, of which varying numbers are* mentioned in the literature In AEBY's representation one finds three, EWART mentions four, which is the number also given by KRAMER and GLASS, NEIL, GILMOUR and GWYNNE, CHURCHILL and BELSEY, LUCIEN and WEBER

In addition to AEBY a trifurcation is described by HUIZINGA, NELSON, FORSTER-CARTER, BROCK, HASSE, PIERRET and his co-workers, and by RAP DWIGHT DAVIS is the only one to describe a bifurcation as the normal finding

Those assuming a quadripartite division, always describe one bronchus as running directly in a lateral direction and supplying an axillary lung segment The existence of an independent axillary segment is therefore closely related to the presence of a quadripartite division of the right upper lobe bronchus In the lungs examined in Groningen, however, a quadripartite division was never found.

A feasible explanation of the way by which some advocates of the quadripartite division arrived at their conclusion is given by BROCK He thinks that it is possible to mistake the light circle, by which on



Fig 11 Right upper lobe bronchus Normal trifurcation
A = apical bronchus D = posterior bronchus P = anterior bronchus

the lateral bronchogram the lumen of the upper lobe bronchus is usually outlined, for an axillary bronchus running directly in a lateral direction CHURCHILL indeed made this error as appears from his description of lipiodol pictures From autopsy examination of lungs erroneous conclusions might be arrived at, if one of the large axillary lateral-branches of the posterior or the anterior bronchi has been pushed up in the direction of the main bronchus, so that the impression of a quadripartite division may be obtained

In the majority of cases, however, the right upper lobe bronchus immediately trifurcates, so that the trifurcation must be taken as the normal (fig 11) Of the three segmental bronchi the apical runs

upwards and slightly in a lateral direction. It soon bifurcates in a very typical way in one branch for the anterior and one for the posterior part of the apex pulmonis This fork-shape is very striking in the lateral pictures The anterior segmental bronchus runs in an anterior and downward direction and also deviates slightly laterally The posterior bronchus runs backwards in a slightly upward direction and also deviates slightly laterally

From the foregoing it will be seen, therefore, that none of the three branches of the right upper lobe bronchus run in a direct lateral course, and consequently one cannot speak of an independent axillary segment One could do so only if there were one bronchus to supply this part, which is certainly not the case It can be seen, on the other hand, that the anterior and the posterior segments meet at the side The dividing plane between these two segments is an approximately perpendicular one, passing consequently through the middle of the axillary part of the lung, so that this is divided into two halves, the anterior half belonging to the anterior segment and the posterior half to the posterior segment

The anatomy of the segmental bronchi is completely in agreement with this, for soon after their origin from the upper lobe bronchus both the anterior and the posterior bronchi give off a large lateral-branch in an axillary direction As these lateral-branches approach the periphery they diverge, so that they supply a wedge-shaped part of the lung between the hilus pulmonis and the surface of the lung, which might be called a pseudo-axillary segment

In the dorso-ventral bronchogram this axillary character of the lateral-branches is scarcely seen It is very clear, however, in the lateral and the oblique lipiodol pictures The apical bronchus too plays a small part in the supply of the axillary part of the upper lobe, by means of a small axillary side-branch This was all closely studied by BROCK and also by RAP

The right middle lobe On account of the simple structure of the right middle lobe bronchus, which shows little variations, there is no significant difference of opinion concerning the division of the middle lobe bronchus This bronchus takes its origin from the front wall of the stembronchus, just opposite the apical bronchus of the lower lobe and about 1 to 1½ inch below the bronchus of the upper lobe It presently bifurcates, the two branches running close to each other in a lateral and anterior-downward direction, one on the lateral side, the other on the medial side in the middle lobe In conformity with this the middle lobe consists of two segments, a medial and a lateral

one At autopsies where a more or less rudimentary middle lobe was found, the same division was also found. This supports the evidence in favour of the regularity of its occurrence

The left upper lobe The structure of the left upper lobe is complicated as it contains a part of the lung which corresponds to the right middle lobe, as is obvious from the anatomy of the bronchial tree. This part of the lung is the anterior lower part of the left upper lobe, and has a tongue-shaped end which has made it customary to call this part of the lung the lingula. Since AEBY first correlated the right middle lobe with the left upper lobe on the grounds of the hyparterial location of both, many opinions have been expressed on this subject. The conception that the lingular part of the left upper lobe is homologous with the right middle lobe, although not generally accepted by embryologists, is indeed the most suited for practical purposes It is, moreover, supported by the occurrence of cases where the lingula is separated from the rest of the upper lobe by a deep sulcus, so that it more or less forms a separate lobe (see fig 16). These cases are not very rare as DÉVÉ has already pointed out. CHURCHILL and BELSEY have also given an excellent description. The reverse situation on the right side, i e. the absence of a division between the upper and the middle lobes, also occurs. One could imagine, therefore, that on the left side the middle lobe bronchus has moved upwards along the main bronchus and has become a side-branch of the upper lobe bronchus.

Now if one considers the ramifications of the left upper lobe bronchus superficially, one is apt to get the impression at first sight that the apical bronchus branches off together with the posterior bronchus and that the separate anterior bronchus has swung round far downwards. In that case there would be a bifurcation similar to that which may accidentally occur on the right side, but more pronounced A closer study of the anatomy of the upper lobe bronchi, in combination with the determination of the appertaining segments, however, teaches the following The left upper lobe bronchus usually shows a bifurcation into an upper and a lower division. From the upper division the anterior bronchus branches off as first side-branch, supplying a part of the lung which includes the middle section of the upper lobe and corresponds to the anterior segment on the right side. It usually extends in the apical direction, on the left slightly more than on the right One might conceive that the apex of the lobe is supplied by the apical bronchus, but part of this region is too far dorsal to call it apical If we accept the conception that the lower (lingular) division is homologous with the right middle

lobe bronchus, and the upper division with the right upper lobe bronchus, the supposition that we shall be able to find here also, in the upper division, three segmental bronchi for the left upper lobe, is more feasible. The posterior part of the left upper lobe is indeed supplied by a separate bronchus, which usually comes off from the back of the upper division, immediately after the anterior bronchus has branched off This bronchus branching off on the dorsal side is considered by some authors as the posterior segmental bronchus of the left upper lobe This view was recently brought to the fore by FORSTER-CARTER, BROCK, and RAP

So according to them the anatomy of the left upper lobe bronchus is as follows The upper division is the counterpart of the right upper lobe bronchus and has like the latter three segmental branches, an anterior, an apical, and a posterior The latter two bronchi usually have a short common apico-posterior stem. JACKSON and HUBER do not assume that there is an independent posterior segmental bronchus in the left upper lobe, but consider it as a mere side-branch of the apical bronchus According to them the upper part of the left upper lobe bronchus divides into two segmental branches only, viz. the anterior bronchus and the apico-posterior bronchus BROCK and also RAP allege that in the part of the upper lobe supplied by the posterior side-branch of the apico-posterior bronchus certain diseased conditions may occur as isolated lesions, but in our opinion this does not mark it as a separate segment In the bronchograms and at autopsy the posterior bronchus is by no means constant and has more the character of a variable subsegmental bronchus The segmental division according to BROCK and RAP is attractive, in view of its symmetry with the right upper lobe Still we prefer the scheme of JACKSON and HUBER, in which the area of the apical bronchus and the posterior side-branch is considered as one segment, the apico-posterior segment

The segmental bronchi of the left upper lobe display a few differences with the corresponding branches on the right side The apical bronchus ascends with a slight outward deviation similar to that on the right, but it shows a slight forward inclination The posterior subsegmental side-branch has a considerably more upward and backward course than the posterior bronchus of the upper lobe on the right The anterior bronchus on the right descends forward and outward and on the left it runs in a less descending direction The axillary area of the left upper lobe is supplied by axillary branches of the anterior and the apico-posterior bronchi, in the same way as on the right

As we know, the right middle lobe bronchus divides into two

branches supplying adjacent segments. In older schemes this same division is also given for the lingula. This is not correct, however The lingular bronchus bifurcates into two branches, one approximately above the other One branch descends in a medio-dorsal direction, the other in a more latero-ventral direction Thus the two

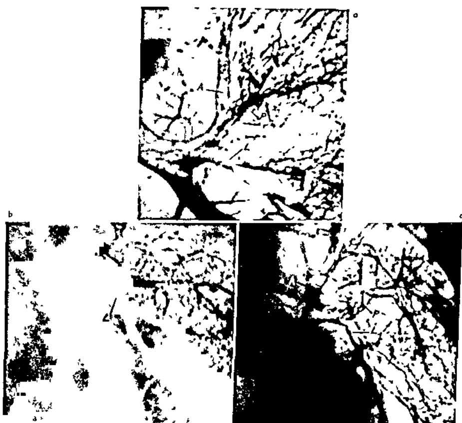


Fig 12 Left upper lobe bronchus *a* normal bifurcation A = apico-posterior, P = anterior bronchus, L = lingula *b* trifurcation *c* abnormal bifurcation, the anterior bronchus branching off from the lingular bronchus

segments overlap in such a way that the superior is situated on the outside and the inferior one on the inside. In this respect we do not quite agree with BROCK, who describes one segment as being right on the top of the other A point to which far too little attention has been paid, in our opinion, is the fact that the lingular bronchus often has a good-sized side-branch running in an axillary direction In a number of cases this bronchus branches off from the lower upper lobe

division, before its final bifurcation into the two segmental lingular branches. In the remaining cases it branches off as a side-branch of the superior lingular bronchus. If this bronchus is strongly developed the two segmental lingular bronchi are usually strikingly small in size.

The lower lobes. Most investigators are in agreement on the division of the right lower lobe, which they usually describe as consisting

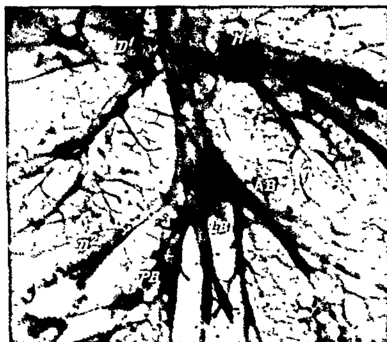


Fig. 13. The bronchi of the right lower lobe. Lateral view.

D¹	apical bronchus	LB -	latero-basal bronchus
D²	subapical (subsegmental) branch	PB	postero-basal bronchus
AB	antero-basal bronchus	M	middle lobe bronchus

of five segments. Of this approximately conic lobe the apex is the area supplied by the apical bronchus. On the right it branches off at the back of the lower lobe bronchus, just opposite to or slightly lower than the branching off of the middle lobe bronchus. On the left side it nearly always branches off a little lower than the upper lobe bronchus, but also at the back of the lower lobe bronchus. Both on the left and on the right sides it runs in the same way, viz. backwards and slightly

downwards It divides into three large branches, one ascending obliquely, one descending obliquely towards the medial part, and the last descending towards the lateral side. The latter two bronchi usually



Fig 14 The bronchi of the left lower lobe Lateral view

D¹ = apical bronchus
AB = antero-basal bronchus
LB = latero-basal bronchus
PB = postero-basal bronchus
D² = subapical (subsegmental) branch

overlap in the lateral lipiodol pictures thus sometimes g erroneous impression that there two branches.

Below the apical segment of wer lobe ther segments, all situated on the diap nown as the

ments. They lie two by two next to and beside one another. NEIL described another segment, the subapical, under the apical segment, belonging to the supply-area of the second dorsal bronchus (D^2 in figs. 13 and 14). This bronchus, however, is not always present and may branch off either from the lower lobe bronchus or from the postero-basal branch of the final ramification. It would, therefore, be incorrect to consider the part of the lower lobe supplied by this inconstant bronchus as an independent segment

The basal segments are supplied by four bronchi, of which the cardiac bronchus is normally present on the right only and branches off from the medial side of the lower lobe bronchus a little below the apical segmental branch This bronchus with its two side-branches — one to the medial front, the other more backwards — supplies the medial front part of the lower lobe, usually called the cardiac segment In some species of animals this segment forms a separate lobe, the so-called infracardiac lobe

The next bronchus to branch off is the antero-basal, (= AEBY's second ventral one) It comes off not exactly on the ventral side but slightly more towards the lateral side from the lower lobe bronchus and, descending outwards and forwards, supplies a segment on the lateral front Finally the bronchus for the lower lobe bifurcates into two branches, one descending to the lateral side and slightly to the front, the other descending towards the back The former, or latero-basal bronchus, supplies a segment in the lateral posterior region, whereas the latter, or postero-basal branch, supplies a segment in the medial posterior region BROCK still makes a distinction between the right and the left, in this respect, that on the right the antero-basal bronchus branches off a little sooner, whereas on the left there is a direct trifurcation RAP, however, found that both on the left and on the right this bronchus usually branches off a little above the final bifurcation A direct trifucation may occur on either side but this is certainly not the rule

The basal bronchi on the left side do not exactly correspond in their courses with those of the right side From their origin they more or less fan out around the heart The space available for the basal segments is not only smaller on the left side, on account of the presence of the heart, but also is of a different shape to that on the right Moreover, a cardiac bronchus is not present on the left side In comparison with the right side, the more fan-shaped course of the basal segmental bronchi becomes very obvious if one compares the oblique bronchograms of the right and the left sides The area of the medial

front, on the right side belonging to the cardiac segment, is supplied on the left side by a side-branch of the antero-basal bronchus running

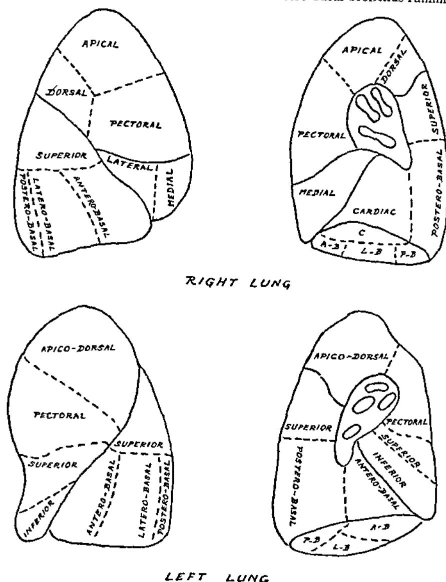


Fig 15 Scheme of the limits of the lung segments In the new international nomenclature (London 1949) pectoral = anterior, dorsal = posterior, apico-dorsal = apico-posterior, superior (lower lobe) = apical

in medial forward direction HUBER's view that this side-branch should be regarded as a separate segmental bronchus, homologous to the cardiac bronchus on the right, is incorrect, in our opinion, because

this side-branch is also present on the right, but does not follow so pronounced a medial course on that side From a comparative anatomical point of view too, a separate cardiac segment on the left is not feasible.

The division of the lung segments

In Groningen the scheme of the division of the lung segments, pictured in fig 15, was composed from data acquired from autopsies and lungs injected with gelatin It is almost in complete agreement with the scheme proposed by the English and American investigators like JACKSON and HUBER and BROCK

The arrangement of the lingular segments, however, is slightly at variance with it, as was pointed out by RAP The two segments of the lingula overlap in two different directions, viz from top to bottom (one might also say from front to back) and from left to right The top segment is at the same time the outermost one In the English schemes the demarcation between these two segments is usually marked by a horizontal line This is not actually the case in our view, which is that the demarcation between the two segments is represented by a backwards rising line There is little point in discussing the exact extent of the segments, as this is closely related to the calibre of the supplying bronchus which varies considerably As a rule the postero-basal bronchus and the corresponding segment are the largest, but at times the latero-basal bronchus and the area supplied by it predominate This may also explain why in JACKSON and HUBER's scheme the postero-basal segment is not seen from the lateral side, whereas it is described in most schemes The same applies to the other segments which are sometimes variously delineated by different authors

JACKSON and HUBER also suggest the presence of a cardiac segment in the left lower lobe, supplied by a medial side-branch of the antero-basal bronchus In our views however, this is not justified for the reasons already cited Moreover, if one were to continue in this way a scheme would result with segments supplied by bronchi not seen or barely seen in the bronchogram Thus it would be useless for practical purposes

Anatomical variations of the bronchial tree

The description of the anatomy of the bronchial tree given in the preceding pages is the scheme which can be considered as normal for the majority of cases Small individual variations often occur,



Fig 16a L = lingula

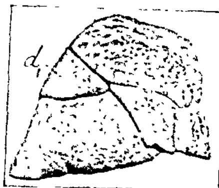


Fig 16b d^1 = right apical lower lobe segment



Fig 16c c = cardiac segment

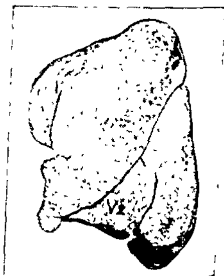


Fig 16d v^2 = left antero-basal segment

Fig 16 A few examples of cases where a lung segment is separated by a sulcus from the other segments of the lobe

without causing a fundamental deviation from the normal scheme. The form of the bronchial tree e g is to a certain extent influenced by factors such as the shape of the thorax and the size and age of the individual, but the fundamental scheme can always be recognized. It goes without saying that an accurate knowledge of this basic scheme is of the utmost importance for anyone practising bronchography, because only then is it possible to interpret a bronchogram One must be fully acquainted with the complicated structure of the bronchial tree

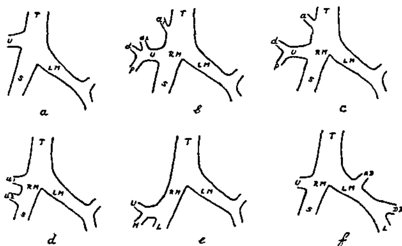


Fig 17 Variations in the anatomy of the bronchial tree

T = trachea RM = right main bronchus LM = left main bronchus S = stem bronchus. U = right upper lobe bronchus M = middle lobe bronchus. L = lower lobe bronchus. AD and DD = upper and lower divisions of the left upper lobe bronchus a = apical, d = posterior, p = anterior bronchus.

In a certain percentage of the cases, however, deviations from this normal construction occur Of these too, the bronchographist should have a thorough knowledge to avoid incorrect interpretation For this reason we shall now deal briefly with these anatomical variations, limiting ourselves to the variations of the bronchi up to and including bronchi of the third order A discussion of the variations in the structure of the smaller bronchi has little practical value, with a few exceptions, as these variations occur in almost every individual and have only a minor importance for diagnostic purposes

The most frequent variations of the anatomy of the bronchi up to and including the third order are the following

The right upper lobe. The bronchus for the right upper lobe sometimes branches off as high as the lower end of the trachea. The bronchogram then gives the picture diagrammatically represented in fig 17*a*. In these cases the stem-bronchus is consequently considerably longer than normal Occasionally only the apical bronchus branches off singly from the lower end of the trachea or from the main bronchus, whereas the upper lobe bronchus branches off from the main bronchus



Fig 18 a^1 = Supernumerary apical bronchus a^2 = apical, p = anterior, d = posterior

in the normal way It may happen that the upper lobe bronchus has nevertheless the normal trifurcation, and in that case therefore a doubling of the apical segment exists (figs 17*b* and 18). Sometimes however only a bifurcation exists, viz into an anterior and a posterior branch (figs 17*c* and 19) Those cases where the apical bronchus branches off separately from the trachea are very interesting from a comparative anatomical point of view, as in many animals this is the normal arrangement.

The bronchus for the right upper lobe may happen to be double (fig 17*d*) In these cases the segmental bifurcation may show all

sorts of variations. The lower one, however, seldom possesses a separate apical branch. Supernumerary bronchi for the right upper lobe usually branch off from the lateral wall of the main bronchus. BROCK, however, described a case of a supernumerary bronchus branching off from the medial wall.



Fig. 13. a = apical bronchus branching off separately from the right main bronchus. Bifurcation of the upper lobe bronchus: p = anterior, d = posterior bronchus. The esophagus also contains some lipiodol.

The segmental division of the normal right upper lobe bronchus may also present variations. RAP found at autopsies a true trifurcation in 60% of the cases. In 40% he saw a bifurcation, one of the branches bifurcating anew after a further few millimeters. Various combinations are therefore possible. For practical purposes it matters little whether a true trifurcation is present, or a bifurcation producing the same three segmental bronchi owing to a new bifurcation of one of its branches. In either case the division of the upper lobe into three segments remains

the same. It may occur that the apical segment is not supplied by one apical bronchus, but instead by two separate bronchi, one branching off from the anterior bronchus and one from the posterior bronchus (e g see fig 32) Very rarely a true bifurcation of the upper lobe bronchus is found as an anatomical variation In that case the division into segments of the upper lobe is quite different from the general rule.



Fig 20 Anatomical variation in the left bronchial tree The apico-posterior bronchus (A) is branching off separately from the main bronchus (L H) The anterior bronchus (P) is branching off together with the lingular division (L) at a lower level

BROCK described a case where the anterior branch of the upper lobe branched off from the bronchus for the middle lobe. This is a very rare anomaly, however

The right middle lobe. Anatomical variations are relatively rare in this bronchus Only very rarely the middle lobe and consequently the middle lobe bronchus may be completely absent. Occasionally the middle lobe bronchus does not branch off from the stem-bronchus, but arises from the upper lobe bronchus In these cases the common bronchus

for the upper and the middle lobes usually branches off from the main bronchus at a low level On account of this the main bronchus has an abnormal length, and a true stem-bronchus is absent (fig 17*e*, see also figs. 107—109). This situation is fully comparable with the normal situation on the left The segmental bifurcation of the middle lobe bronchus very seldom shows variations of any importance

The right lower lobe The most frequent variation is the absence of the cardiac bronchus This occurs in about 20% of all cases Occasionally the antero-basal branch is absent, but this, however, is rare A supernumerary apical bronchus is occasionally encountered Often a considerable difference in calibre exists in the three basal branches. Usually the postero-basal branch is the largest, but sometimes the latero-basal branch predominates

The left upper lobe This lobe shows the greatest amount of anatomical variations As a matter of fact in no more than about 50% of all cases is the normal anatomy found Considering the rather complicated structure of the bronchial tree of the upper lobe this is not surprising.

The most interesting variation of the large bronchi is the following the upper and the lower divisions of the upper lobe bronchus branch off separately from the left main bronchus (fig 17*f*) This corresponds with the normal anatomy of the bronchi for the upper and middle lobes on the right Occasionally only the apico-posterior bronchus is found to branch off separately from the main bronchus, whereas the anterior bronchus branches off together with the lingular division at a lower level (fig 20) These cases are very rare however

Variations in the segmental bronchi occur most frequently A frequent variation is that the anterior bronchus branches off at the bifurcation of the upper and lower divisions of the upper lobe bronchus In that case a trifurcation of the upper lobe bronchus is present (fig 12*b*) and the anterior bronchus is usually abnormally wide, so the anterior segment also occupies a larger area Sometimes the anterior bronchus is still further displaced and branches off from the lingular division (fig 12*c*) In these cases the upper division has a good-sized side-branch, very markedly resembling an accessory anterior bronchus This bronchus, however, runs more in a forward direction than does the anterior bronchus in normal cases

The frequent occurrence of a side-branch of the lingular division, running in an axillary direction has already been referred to in the discussion of the normal anatomy It may even be the case that the area supplied by this branch is larger than that supplied by the

Anglo-Saxon	French	Dutch	German
upper lobe			
1 apical = antero-superior	1 apicale	1 apicale	1 apicalis
2 pectoral = ventral = antero-lateral = antero inferior	2 ventrale supérieure	2 pectorale	2 pectoralis = ramus anterior
3 paravertebral = subapical = dorsal = posterior = postero lateral = lateral	3 dorsale supérieure	3 axillaire	3. axillaris = ramus posterior
4 axillary	4 parabronche externe 1		
middle lobe			
1. medial = anterior middle	1 supéro-interne = antéro interne	1. mediale	1 paramediastinalis = ramus anterior
2 axillary = lateral middle	2 inféro externe = postéro-externe	2. laterale	2 costalis = ramus lateralis
	3 parabronche externe 2		

lower lobe 1 apical = superior = dorsal	dorsale inférieure 1, 2 3 en 4 1 = dorsal moyen	1 1ste dorsale bronchus	1 apico horizontalis
2 posterior basic = " basal = postero-basal - paravertebral - posterior medial		2 medio dorsale bronchus	2 basilaris posterior
3 anterior basic = antero basal = antero lateral	ventrale inférieure 2, 3 4	3 2de ventrale bronchus	3 axillo-basilaris anterior = bronchus terminalis externus
4 axillary basic basal middle basal lateral basic lateral basal postero lateral latero basal	parabronche externe 3 4, 5	4 latero ventrale bronchus	4 axillo basilaris posterior
5 cardiac medial medial basal - antero medial	5 parabronche interne	5 cardiale	5 basilaris anterior

Survey composed by RAP, of the names of the segments of the right lung in the various schemes

superior and inferior lingular segments together. When interpreting these cases, however, the possibility should always be borne in mind that we are dealing with a displacement of the *anterior bronchus*. This is sometimes very difficult to decide with certainty. The occurrence of an axillary side-branch of the superior lingular bronchus is very frequent

The left lower lobe The variations which may occur here are not numerous Occasionally the antero-basal bronchus is absent, so in that case there are only two basal segments. Sometimes the antero-basal bronchus does not branch off directly from the lower lobe bronchus, but branches off from the postero-basal or the latero-basal bronchus Occasionally a supernumerary apical bronchus is present (e g. see fig 34).

The variations in the anatomy of the bronchial tree and the lung segments described here are those which occur most frequently and which are important for bronchography. As has been mentioned above a detailed discussion of the variations in the anatomy of the sub-segmental and smaller bronchi has no practical purpose

The nomenclature

The nomenclature of the bronchial tree and the bronchopulmonary segments is far from being unanimous in international literature This is obviously a very undesirable situation, as the very different names used by the various authors for the same bronchus or the same segment are apt to cause misconceptions. In addition sometimes even the terminology of a segmental bronchus and its appertaining bronchopulmonary segment differ from each other, thus increasing the confusion

In the survey on the pages 48 and 49, composed by RAP, the names were set down which the lung segments, and usually also the supplying bronchi, have been given in course of time in the various schemes This survey clearly illustrates the divergencies in international nomenclature Various authors have already pointed out the disadvantages of this situation and have tried to create uniformity in the terminology of the bronchial tree and the bronchopulmonary segments Unfortunately until July 1949 they had not yet succeeded, even in the more recent F d Americ ions quite different names are found al b

A satisfactory nomencl ossess requirements It should be as s al as p ames of the segm st be

identical Furthermore the name of each segmental branch should reflect as far as possible the special character of the bronchus Identical names of segmental bronchi must be avoided to the utmost Finally it is necessary to have identical names for the homologous bronchi in the right and left lungs.

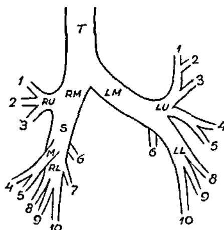


Fig 21 The nomenclature and the numbering of the bronchial tree (London July 1949)
T = trachea RM = right main bronchus. LM = left main bronchus (S = stem-bronchus)
RU = right upper lobe bronchus. LU = left upper lobe bronchus M = middle lobe bronchus.
RL = right lower lobe bronchus LL = left lower lobe bronchus
Right bronchial tree 1 = apical 2 posterior 3 = anterior 4 = lateral 5 = medial 6 = apical. 7 = cardiac 8 = antero-basal 9 = latero-basal 10 = postero-basal segmental bronchus. Left bronchial tree 1 + 2 = apico-posterior 3 = anterior 4 = superior lingular 5 = inferior lingular 6 = apical 8 = antero-basal 9 = latero-basal. 10 = postero-basal segmental bronchus.

Even as far as the nomenclature of the large bronchi is concerned, no agreement had yet been reached The concept *stem-bronchus* in particular is often incorrectly used Many authors speak of the left stem-bronchus instead of the left main bronchus In our opinion this is incorrect on historical grounds The name stem-bronchus should be exclusively used to denote on the right side that part of the main bronchus situated between the branching off of the upper and middle lobe bronchi The correct nomenclature of the large bronchi is set down in fig 21

In regard to the nomenclature of the segmental bronchi and the appertaining bronchopulmonary segments we proposed the following names as used in the Groningen university clinic

Right upper lobe bronchus	apical	bronchus	(segment)
	dorsal	„	„
	pectoral	„	„
Right middle lobe bronchus	lateral	„	„
	medial	„	„
Right lower lobe bronchus	superior	„	„
	cardiac	„	„
	antero basal	„	„
	latero basal	„	„
	postero-basal	„	„

Left upper lobe bronchus	ascending division	apico-dorsal bronchus (segment)	apical branch dorsal branch
		pectoral bronchus (segment)	
	descending division = lingula	superior lingular bronchus (segment)	
		inferior lingular bronchus (segment)	

Left lower lobe bronchus	superior	bronchus	(segment)
	antero-basal	„	„
	latero-basal	„	„
	postero-basal	„	„

This nomenclature as has been used in Anglo-American literature and by us was quite logical It had the great advantage of being simple and making clear in the shortest possible way the special topography of the bronchi concerned and the corresponding segments

The International Congress of Oto-Rhino-Laryngology was held at London in July 1949 Here the opportunity presented itself to bring men together from different parts of the world, who are interested in the subject of the anatomy of the bronchial tree. A meeting was arranged of these men, in order to discuss the subject of nomenclature and it was held on July 21st 1949 under the chairmanship of Dr V E NEGUS from London, England The following men attended the meeting CLERF, HOLINGER, CHEVALIER JACKSON, TUCKER (U S A), APPLETON, BROCK, NEGUS (chairman) and NICOLS (Great Britain), LEMOINE and SOULAS (France); BARRETTO (Brasil), EEMAN (Belgium), Huizinga (secretary) (Holland); KJAER (Denmark), LEEGAARD (Norway).

The meeting was crowned with succes in this way that, after a discussion which lasted for four hours, the following nomenclature was adopted unanimously

Right lung		*Left lung*		
Upper lobe	apical	Upper lobe	upper division	apico-posterior
	posterior			anterior
	anterior		lower division (lingular)	superior
Middle lobe	lateral			inferior
	medial	Lower lobe		apical
Lower lobe	apical			antero-basal
	cardiac (medial-basal)			latero-basal
	antero-basal			postero-basal
	latero-basal			
	postero-basal			

From the above one can see that most of the bronchi were given one name, except for two which were given a double name, viz the cardiac branch on the right was also named medial-basal, and the lower division on the left was also assigned as the lingular division

It is understood that the decision of this Committee is not binding to the whole world, but it is sincerely hoped that this new nomenclature will be universally adopted As far as the clinic in Groningen is concerned, we heartily welcome this new terminology and we are using it in this book

In the discussion of bronchography, which is in the main nothing but applied anatomy, the names of the segmental bronchi constantly recur To interpret the bronchograms it is very necessary to mark the various segmental bronchi clearly on the X-ray pictures The simplest way to do so is by means of a fixed numbering of the segmental bronchi Thus they can be immediately located on the bronchograms This has also been suggested by JACKSON and HUBER

The numbering used by us is the same for all bronchograms in the following chapters (see fig 21) The segmental bronchi are numbered consecutively from top to bottom on the bronchogram, the corresponding bronchi of the right and the left bronchial trees bearing the same numbers

The numbering is as follows

	Right bronchial tree		*Left bronchial tree*
Upper lobe	1 apical bronchus	Upper lobe	1 — 2 apico posterior bronchus
	2 posterior bronchus		
	3 anterior bronchus		3 anterior bronchus
Middle lobe	4 lateral bronchus		4 superior lingular bronchus
	5 medial bronchus		5 inferior lingular bronchus

Lower lobe	6 apical bronchus 7. cardiac bronchus 8 antero-basal bronchus 9 latero-basal bronchus 10 postero-basal bronchus	Lower lobe	6 apical bronchus 8 antero-basal bronchus 9 latero-basal bronchus 10 postero-basal bronchus

Number 7 for the cardiac bronchus on the right is absent in the numbering of the left bronchial tree, as it does not have a cardiac side-branch The numbering of the branches of the bronchial tree, as given here, offers enormous advantages, as has been shown by our experience, because of its simplicity. It was also accepted at the International Congress of Oto-Rhino-Laryngology (London July 1949), and it is to be hoped that, like the new nomenclature, it will find international acceptance in future

CHAPTER II

THE PHYSIOLOGY OF THE BRONCHIAL TREE

This chapter on the physiology of the bronchial tree is especially intended to deal with those aspects of the subject, which are important from the point of view of bronchography

The bronchial tree is the system of air passages through which air enters and leaves the lung Deep respiratory excursions and also certain changes in posture cause considerable variations in the relative position of the components of the bronchial tree and also in the size and shape of their lumina The anatomical structure of the bronchial tree (cartilaginous rings, elastic tissue, smooth muscle) permits such changes to occur

As the result of observations made during bronchoscopic examinations, much has been learned about the movements of the larger bronchi under such circumstances Excellent descriptions of these movements have been given by various observers, particularly by BRUNINGS and CHEVALIER JACKSON It has long been recognized that a distinction has to be made between pulsatory and respiratory movements of the bronchial tree. The former are due to the pulsations of the large blood vessels and the heart, and are not of much importance in bronchography. The latter, however, are of considerable significance, but hitherto have not attracted the attention they merit Bronchography enables us, by a simple method, to study the bronchial tree in the living subject A considerable number of patients have been submitted to this procedure at Groningen for some years past, and on occasion it was found that the bronchi were normal Advantage was taken of such occasions to study points of physiological interest Many previous observations were confirmed and some new facts were elicited, as the use of contrast oil permitted a follow up on the movements of the peripheral bronchi, about which much less was known

Alteration in the position of the bronchi during respiration

Changes in the position of the peripheral bronchi during respiration may be considerable In the region of the bifurcation such changes take place only to a slight extent, as was pointed out by MACKLIN

If it were otherwise serious consequences would ensue, e g. constriction of the big vessels. *Changes in the position of the larynx have little effect* on the position of the bronchi (see figs. 22 and 23). These are lateral pictures taken in the case of a girl of 16 years of age Fig 22 was taken with the head bent markedly forwards and fig. 23 with the head

Fig 22 Position and length of trachea when head is flexed

bent markedly backwards The trachea is marked with a dotted line from the bifurcation to the cricoid cartilage and the vertebrae are numbered

It will be observed that in both instances the position of the bifurca*tion remains at the level of the 4th* thoracic vertebra, but that of the cricoid cartilage changes from the level of the 7th cervical vertebra

to that of the 5th. The pictures were taken with the tube at a distance of 2 1/4 yards, and the organs were therefore projected in approximately their actual dimensions Measurement showed that the trachea was elongated from $3^{1}/_{2}$ to 5 inches, which represents an increase in length of about 50% When figs 22 and 23 are compared



Fig 23 Position and length of trachea when head is extended.

it is apparent that in addition to the elongation of the trachea there is a narrowing of its lumen This is a well known occurrence and is important for clinical purposes When an asphyxiating patient's head is bent backwards for tracheotomy the degree of occlusion of the trachea is increased The accompanying pictures show clearly why this is so

The movements of the larynx therefore have little or no effect on the position of the bifurcation. However, conversely, it is to be noted that a sudden push on the bifurcation is perceptible in the larynx



Fig. 24. Bronchi of the left lower lobe. Inspiration

and is known as OLIVER-CARDARELLI's sign. It is of interest that this sign of aortic aneurysm is chiefly observed in somewhat advanced age, when the trachea has become hardened by ossification

During respiration the position of the bifurcation varies very little. BRUNINGS and WEINGAERTNER stated that during a maximum

respiratory excursion the bifurcation does not descend more than 3/8 inch on inspiration Confirmation of this observation is provided by figs 24 and 25, which were made with the tube 2 1/4 yards distant,



Fig 25 The same bronchi as in fig 24 Expiration

as were the other pictures illustrating this chapter They are the X-rays of the normal bronchi of the left lower lobe of an 18 years old boy taken on deep inspiration (fig 24) and expiration (fig 25) The considerable change in position of the peripheral bronchi is immediately apparent In fig 24 they reach the level of the 11th

thoracic vertebra and in fig 25 the level of the 9th thoracic vertebra The bifurcation, however, at the level of the 6th thoracic vertebra only alters its position to the extent of 3/8 inch Figs. 26 and 27 also illustrate the foregoing. Slight lateral movements to the left or to the right also occur

Figs 26 and 27 are bronchograms of the normal bronchi of the right upper lobe of a 27 years old man. They were taken on very deep expiration (fig. 26) and inspiration (fig. 27) and illustrate very clearly the typical trifurcation of the right upper lobe bronchus The bifurcation and the big bronchi remain relatively fixed during respiratory movements because the lung tissue in this region is rather fixed (mediastinum, spine) The smaller bronchi, on the other hand, extend outwards into lung tissue which moves freely during respiratory movements, and the bronchi move with it.

It is not infrequently stated in textbooks on Physiology that the peripheral bronchi are stretched during deep inspiration and the impression that this is so may be conveyed by figs. 24 and 25 It must be borne in mind, however, that these pictures only reproduce the projection in the perpendicular plane. On account of the straighter shape of the bronchi in fig 24, as compared with fig 25, they appear to have become elongated to a greater extent than is actually the case.

The investigations of MARCUS and HILBER on this subject are of much importance They have demonstrated that the bronchi pursue a spiral course and that during inspiration the spiral is to some extent unwound This spiral-shaped structure of the bronchial tree is particularly well seen on stereo-roentgenograms, using lipiodol as a contrast medium The spiral structure of the bronchi has the great advantage of permitting the bronchi to adapt themselves to the movements of the surrounding lung tissue, without becoming stretched In addition the curves of the spiral possess the advantage of offering less resistance to the flow of air than would more angular curves At the ramifications of the bronchial tree, also, sharp angles are never found, because, if such were the case, undesirable eddies would tend to occur in the current of air Pictures of the bronchi taken in one plane only, may sometimes convey a very misleading impression in this respect

It is often stated that the peripheral bronchi fan out on inspiration but this is certainly not generally so Some bronchograms, particularly lateral views, may, however, give this impression, as will be seen in figs 28 and 29. They are the lateral pictures of the right bronchial tree of a boy of 17 years of age, taken on deep expiration and inspiration

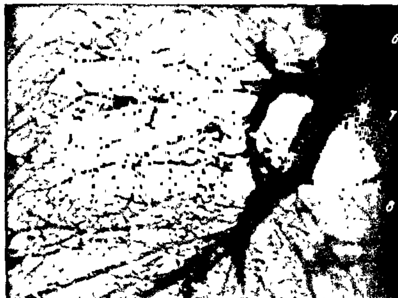


Fig. 26 The bronchi of the right upper lobe Deep expiration



Fig. 27 The same bronchi Deep inspiration

respectively In both pictures the middle lobe bronchus with its two segmental branches is clearly seen. The angle between these branches appears bigger in the bronchogram *taken during inspiration* but again we must bear in mind that these pictures are those of a projection in one plane, the perpendicular, and as the two branches are situated mainly in a horizontal plane, they do not really indicate the size of the angle between them

Some investigators, such as HUDSON and JARRE, appear to have reached conclusions more or less contrary to the views expressed above An explanation of the conflicting views on the subject under review may be forthcoming when figs. 24 and 25 are compared with figs 28 and 29 In figs 24 and 25 the angles between the bronchi in *the left lower lobe are smaller during inspiration. The displacement of* the diaphragm is very marked in this case and the whole structure of the lower lobe bronchi is pulled downwards to a considerable extent This has a far greater effect than have the movement of the ribs and the dilatation of the intercostal spaces. The young man in figs. 28 and 29, on the other hand, displays respiration mainly of a costal type It is exactly this, which gives the impression in lateral projections of considerable spreading of the bronchi.

Variations of the predominating type of respiratory movement, costal or diaphragmatic, are responsible for the changes observed in individual cases *In addition, as the picture is of a projection* in one plane, it can never reproduce in depth that which it is intended to portray Figs 26 and 27 show the three classical segmental branches of the upper lobe bronchus on the right side, viz the apical passing upwards, the posterior passing laterally and posteriorly, and the anterior passing laterally and anteriorly. The latter two bronchi also have axillary side-branches These are clearly seen in figs 26 and 27. In fig 27 one gets the impression that these branches lie more closely together on inspiration than on expiration (fig 26), whereas, in actual fact, they spread out more widely on account of the *considerable displacement in a dorso-ventral direction* caused by costal respiratory movement

Luminal changes during respiratory movements.

The diameters of the bronchi increase during inspiration and diminish during expiration This can be clearly demonstrated by bronchoscopy In adults, during normal respiration, such changes take place only to a very slight extent *but in children they are more pronounced*, due to the softer tissues of the air passages This forms the basis of

the mechanism of valvular stenosis During vigorous respiratory movements in the adult appreciable luminal changes can be observed

ROHRER explained the foregoing in the following manner. During inspiration the whole lung expands and the bronchi increase in length They also increase in diameter because there is a radial pull on their walls During maximum inspiration he considers that there is a very definite increase in length and a slight increase in diameter of the bronchi. The resistance offered to the current of air remains unchanged in the various degrees of stretching of the lung On this basis the velocity of the current of air was calculated for varying degrees of pressure.

BRUNINGS considered that the changes in the lumina of the bronchi are due to variations in pressure in- and outside the bronchi, but these could only be of importance if the air current were a strong one. BRUNINGS has rated this variations in pressure far too high

In an elastic organ like the lung the pressure in the alveoli soon adjusts itself and restores balance with the pleural pressure, throughout the lung This is therefore approximately the pressure prevailing in the alveoli *around* any particular bronchus The pressure *within* the bronchus is determined in accordance with laws governing the pressure of flowing gases The pressure decreases (on expiration) or increases (on inspiration) to atmospheric pressure from the alveoli to the nose. During deep inspiration, therefore, the pressure within the bronchus is higher, but on expiration the reverse is the case. The latter is particularly marked during acts such as coughing; by means of the bronchoscope the bronchial walls can be seen to collapse suddenly. The differences in pressure in- and outside the bronchi are, therefore, of great significance

When bronchograms taken during inspiration and expiration are compared, it will be seen that the luminal changes, in adults as well as children, are considerably greater than is usually described in standard textbooks on Physiology Reference to figs 28 and 29 will show considerable differences in the large bronchi and even in the trachea These luminal changes take place in all of the pulmonary lobes and become much more marked towards the periphery, because of the change in anatomical structure from cartilaginous rings, more and more smooth muscle tissue

The points under discussion are very clearly illustrated in fi[illegible] and 27 On measurement on expiration and on inspiration, the [illegible] meters of the right main bronchus were found to be 14 [illegible] 16 mm respectively, of the upper lobe bronchus 8 mm and [illegible] of the first subdivision branches 3 mm and 5 mm. Tow[illegible]

periphery many bronchi were found in which the diameter was more than doubled, so these bronchi were more than 4 times as large in deep inspiration as they were in deep expiration.

There is, of course, a physiological purpose in the foregoing. The



Fig 28 Right bronchial tree Deep expiration

amount of dead space must be considerably smaller on deep expiration than on deep inspiration, and the marked luminal changes in the peripheral bronchi play a very important role in expectoration The velocity of the air current under various circumstances must differ from the ones estimated according to ROHRER's calculation.

The pictures figs 24—29 were taken while the breath was held and the lungs were therefore at rest Under such circumstances, the differences in respiratory pressure cannot affect the changes observed, in the manner described by BRUNINGS This becomes still



Fig 2? Right bronchial tree Deep inspiration (Compare fig 28)

more obvious in a series of pictures taken during the course of one breath and employing a technique similar to that used in gastric X-ray technique This is illustrated in fig 30, where the breath was interrupted and held four times

It is of the right lung of a 22 years old man whose bronchial tree

5

was found to be normal, by means of bronchography It was X-rayed in 4 stages *from deep expiration (1) to deep inspiration (4)*. The gradually increasing expansion of the ramifications is apparent In the state of rest, *in which the pictures were taken*, the pressures inside and outside of the bronchi were equal. Some bronchi are seen which have a diameter of 1.5 *mm in picture 1, and of 4 mm in* picture *4*

It must, therefore, be concluded that the *widening of the bronchi* is due to the expansion of the lung as a whole. It is remarkable that this widening of the bronchi should take place to the extent which it does The relation of lung volume at maximum expiration to that at maximum inspiration is approximately as 1 to 4. It has always been assumed that this was chiefly due to changes in the volume of pulmonary tissue proper If, however, we were to assume this to be the same in the small bronchi, it would cause linear changes in the order of 1 to 1 6, but it is evident from these pictures that the diameter of the peripheral bronchi may be increased 2 to 3 times

When seeking an explanation of these observations the following points must be considered. It is possible that the length of the peripheral bronchi is not increased during inspiration on account of the spiral structure of the bronchial tree In such a case the changes in volume of the lung will only cause luminal changes in the bronchi If the volume of a particular peripheral bronchus increases equally with that of the lung from 1 to 4, the change in diameter approaches more closely to that calculated, viz *from 1 to 2. Even then the great* luminal changes of bronchi a few mm. in diameter, and still more of *those containing cartilage, remain very remarkable, and* possibilities such as the following must be taken into consideration.

In contrast to anticipated findings based on anatomical structure, the peripheral bronchi are possibly more easily stretched than pulmonary tissue This would lead support to the conception of von Neergaard, that the surface tension of the alveoli is of greater importance than the elasticity of the pulmonary tissue

The other possibility is that synchronously with the respiratory movement the tonus of the bronchial muscles changes But it seems not probable that these smooth muscles can follow the frequency of the respiration

Active movements. Peristalsis

Active movements are very interesting from the physiological point of view The extensive muscular tissue *of the bronchi*, which is so potent a factor in some pathological processes such as asthma, would



Fig. 30. Pictures of the right bronchial tree from deep expiration (1) to deep inspiration (4)

then be considered as taking a very active part in the regulation of respiration Much has been written about the physiology and function of the bronchial muscles, but many of the views expressed have been conflicting Some of the latest experimental work on dogs, done by ELLIS, has made it very probable that *the luminal changes during* respiratory movements are purely passive, being the result of radical traction, when the lung expands.

Peristalsis of the bronchi has also been much discussed and was usually dismissed on the grounds of the structure of the bronchial muscles. Some *investigators however tenaciously held to the view* that peristalsis does occur, and attached much importance to it, especially peristalsis of the small bronchi, in the removal of secretion. In latter years many communications have been published by investigators who claim to have observed peristalsis in bronchography, *nearly always during fluoroscopic examination.*

Figs 24—30 do not support the views in favour of peristalsis. Not one of these pictures show a trace of peristalsis, nor was it observed in any of many hundreds of bronchograms. The picture of the bronchi may vary considerably as a result of respiratory move- *ments, and might be misinterpreted*

Attention is drawn to the pictures of the bronchi in figs 24. and 25 They are only slightly filled with lipiodol and on inspiration clearly visible lumina are seen with a coating of lipiodol on the walls On expiration the picture is very irregular and small drops of lipiodol *are seen interspersed with air bubbles* This is a picture which resembles peristalsis, but is to be explained by luminal changes. The lipiodol on opposite walls comes into contact and drops are formed, as a result of surface tension Pictures of this kind appear in the literature, sometimes interpreted and explained incorrectly It should also be remembered, that the bronchi undergo respiratory displacement and in consequence fluoroscopic examination does not always permit an accurate interpretation.

The contrast oil also moves with respiration, *rising during expiration* and falling during inspiration. On deep expiration the considerable luminal changes in the periphery cause the oil to be pressed out In figs 26 and 28 it will be seen that the large bronchi are much more fully filled with lipiodol, on expiration This is very important as the same thing *happens with secretion* If it were not so, the secretion might easily be deposited, obstruct a bronchus, and result in atelectasis. The pictures clearly show the importance of deep breathing in the presence of secretion, because *movement of the*

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The movement of the ciliated epithelium of the bronchial mucous membrane is, of course, also of great importance in expectoration. It also is an important factor in expelling lipiodol, injected into the trachea, as was demonstrated by KNIPPING, PONNDORF and LEEGAARD.

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Peristalsis of the bronchi has also been much discussed and was usually dismissed on the grounds of the structure of the bronchial muscles. Some investigators however tenaciously held to the view that peristalsis does occur, and attached much importance to it, especially peristalsis of the small bronchi, in the removal of secretion. In latter years many communications have been published by investigators who claim to have observed peristalsis in bronchography, nearly always during fluoroscopic examination.

Figs. 24—30 do not support the views in favour of peristalsis Not one of these pictures show a trace of peristalsis, nor was it observed in any of many hundreds of bronchograms The picture of the bronchi may vary considerably as a result of respiratory movements, and might be misinterpreted.

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publication in 1922, disclosing their findings, bronchography with lipiodol as the contrast medium quickly came into general use, as a method of investigation in various pulmonary lesions In the course of time bronchography developed into a highly refined diagnostic procedure, particularly in experienced hands

Lipiodol

Lipiodol, a French preparation, is a pale yellow oil, thickly fluid at room temperature, consisting of a compound of 40 per cent by weight of iodine with non-saturated fatty acids dissolved in poppy-seed oil The specific gravity is 1,350 Lipiodol is insoluble in water or alcohol. When properly prepared, lipiodol contains no free iodine. If it shows a brownish discoloration or has become turbid it often contains free iodine, due to decomposition, and must therefore never be employed for intrabronchial use Alkalies liberate iodine from lipiodol, this is done by the saliva, and also to a greater degree by the intestinal juices The gastric juice does not affect lipiodol Owing to the absence of free iodine, lipiodol is not injurious to the mucous membrane of the air passages

Some investigators, e g FORESTIER, ascribed certain antiseptic qualities to lipiodol, but this is probably incorrect, as was shown by the investigations of NEUSWANGER and BROWN NEUSWANGER cultured bacillus coli, streptococci and staphylococci on agar plates containing lipiodol, and stated that the various bacteria grew in normal colonies BROWN mixed the purulent sputum of a patient, suffering from bronchiectasis, with an equal quantity of lipiodol, and allowed this mixture to stand for 48 hours He subsequently inoculated some of it into a culture medium but in this case also the bacteria grew normally

It is a fact proved by experience, that after an examination of the air passages by means of lipiodol, infection rarely ever occurs A few workers have even claimed that it has a favourable influence on purulent chronic inflammatory processes

The greater part of the lipiodol, introduced into the bronchi, is ejected again from the air passages by coughing, especially when the influence of the anaesthetic, applied for the examination, has ceased It is generally assumed that within 3 to 4 hours after its introduction 60 to 80 per cent of the total quantity used has been expectorated again A small quantity remains in the lung for some time, especially when a considerable amount of the oil has reached the alveoli

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CHAPTER III.

BRONCHOGRAPHY.

GENERAL CONSIDERATIONS

History

Bronchography, i e the X-ray examination of the deeper air-passages after the introduction of a contrast medium, was first done unintentionally It has been observed that when an opaque meal containing bismuth or barium was given for X-ray examination of the esophagus, some of the contrast medium entered the bronchial tree either by aspiration or through an esophago-tracheal fistula. The significance of this observation went unheeded for a long time, and eventually when it was recognized, it soon became apparent that the contrast media used for X-ray examination of the gastro-intestinal tract were not suitable for intrabronchial use, and were sometimes injurious

Much experimental work was done on this subject, particularly in the U S A As early as 1917 WATERS, BAYNE JONES and ROWNTREE experimented on dogs, using an iodoform emulsion This proved to be impracticable because many of the test animals died from the toxicity of the preparation CHEVALIER JACKSON (1918) blew a bismuth oxide powder into the air passages through a bronchoscope. Reasonably satisfactory results were achieved by this method but there were some disadvantages associated with it. It necessitated the introduction of a bronchoscope, and the complete insolubility of the contrast medium made its use undesirable for several reasons, among them being the possible formation of broncholiths. LYNAH and STEWART (1920) used a suspension of a bismuth salt in olive oil but this, too, did not prove very satisfactory. Other contrast media employed on humans or test animals were, collargol, thorium and sodium bromide, but all of them had to be abandoned as unsuitable and injurious

In 1921 the French investigators SICARD and FORESTIER discovered the excellent properties of lipiodol as a contrast medium for the X-ray examination of the deeper air passages After their epochmaking

publication in 1922, disclosing their findings, bronchography with lipiodol as the contrast medium quickly came into general use, as a method of investigation in various pulmonary lesions In the course of time bronchography developed into a highly refined diagnostic procedure, particularly in experienced hands

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down locally in the lung ROGER and BINET were of the opinion that this was done by enzymes, a process they called „lipiodierèse". GUIEYSSE and PELLISSIER sought to prove that histologic-phagocytic processes were also of importance in this process. HEUBNER expressed the view that microscopic drops of lipiodol could pass unchanged through the epithelium of the finest bronchi and alveoli and could thus be removed from the lung. The lipiodol removed from the lung is further broken down in the body, the iodine thus liberated being excreted by the kidneys It is demonstrable in the urine and can be quantitatively determined

Certain observations, however, cast very definite doubt on the view that lipiodol could be broken down locally in the lung. BERNIER and PIERON, elaborated a method to determine, quantitatively, the excretion of iodine in the urine They stated that after the intratracheal administration of lipiodol the excretion of iodine in the urine was greatest during the first two days and rapidly decreased after that, to continue subsequently for a very long time at an almost constant rate until all the lipiodol had disappeared from the lungs. They also showed that if a great quantity of lipiodol was swallowed during or shortly after the examination, the quantity of iodine excreted during the first few days was considerably greater, declining afterwards to a constant low level.

KNIPPING and PONNDORF observed that some patients, after an examination with jodipin — an almost identical German preparation — retained a considerable quantity of jodipin in the lung. In these cases, there was only a slightly increased excretion of iodine in the urine, but the amount was much greater in the case of patients who had swallowed a lot of jodipin during the examination As a result of these observations experiments were carried out on animals. A dog's trachea was cut through and sutured to the skin of the neck. If jodipin was introduced into the air passage by way of the tracheostoma, very little increase in the excretion of iodine in the urine resulted, if, however, the jodipin was mixed with the food, a markedly increased excretion of iodine resulted. From this they inferred that there is no local absorption of any importance in the lung itself, but that, shortly after the examination, considerable quantities of jodipin are expectorated and involuntarily swallowed The remaining jodipin is gradually brought upwards in small quantities by means of the movement of the ciliated epithelium and is also swallowed This may explain the protracted continuous excretion of iodine

A few years ago the view of KNIPPING and PONNDORF was completely

affirmed by LEEGAARD, who experimented on rabbits. Similar observations were also made in man Lipiodol introduced into the air passage of patients, who have undergone an extirpation of the larynx, results in only slightly increased excretion of iodine in the urine

To summarize, the local absorption and break down of lipiodol in the lung only takes place to a very slight extent Nearly all the lipiodol introduced is gradually expectorated or, after removal by the movement of the ciliated epithelium, swallowed, broken down in the intestinal tract, absorbed and eventually excreted by the kidneys This process usually takes a very long time, and lipiodol sometimes remains in the alveoli for months and may be visible on X-ray examination Gradually, however, lipiodol is removed and eventually completely disappears

The fact that sometimes during or shortly after the lipiodol examination a not inconsiderable quantity of lipiodol is swallowed, has another practical significance Occasionally toxic or allergic phenomena occur, e g coryza, epiphora, hoarseness, urticaria, edema, especially facial edema, and exceptionally a temporary swelling of the thyroid gland Usually these phenomena are harmless and only last for a few days However, SCADDING in his account of the various allergic reactions, occurring in a series of over 2900 bronchographies, described one fatal case, the patient dying of a generalized papular and pustular skin eruption

When patients, allergic to iodine, swallow a considerable amount of lipiodol during or shortly after the bronchography, it is not surprising that a reaction occurs, in view of its rapid decomposition and absorption in the intestine Some authors, e g ARCHIBALD and BROWN, advocate the rapid and complete removal of lipiodol as soon as possible from the stomach by lavage, when it appears that a considerable quantity of lipiodol has been swallowed

In the Groningen clinic the view is held that allergy of the patient to iodine is not an absolute contra-indication to bronchographic examination, if proper care is taken to ensure that during and after the introduction of lipiodol none or only very little of it gets into the intestinal tract

Occasionally, the presence of lipiodol in the lung may be injurious to the lung Several communications dealing with this are to be found in the literature WESTERMARK described 4 cases of atelectasis of a part of the lung, appearing 10 to 15 minutes after the introduction of lipiodol The phenomenon of atelectasis spontaneously disappeared after the expectoration of the lipiodol, and only occurred in

cases where the bronchi proved to be normal. In areas where patho-logically altered bronchi were present, he never saw atelectasis as a result of the lipiodol examination.

ARCHIBALD and BROWN pointed out that during the introduction of lipiodol infectious material from nose or throat may be carried into the lung, thus possibly causing a new infection in already diseased tissue. In exceptional cases a fever peak is observed and very rarely an acute exacerbation of an infectious process is encountered. Thus, GRILL described a pulmonary abscess following lipiodol examination, the patient dying 14 days later. ARCHIBALD and BROWN, LICHTWITZ and other authors also described similar cases. LENK and HASLINGER observed a pneumonia after bronchography. It is questionable whether lipiodol, as such, or the anaesthesia with its ever present possibility of aspiration into the deeper air passages are, of themselves, harmful. The "congestion pulmonaire", as described by AUMONT, LEURET, SECOUSSE and CAUSSIMONT, was probably due to the excessive quantities of lipiodol they used, e.g. as much as 50 cc for a unilateral examination.

FOKKE MEURSING stated that lipiodol may cause chronic inflammatory changes, which he named pneumonolipòsis. WEINBERG and earlier LANDAU observed the same in their experiments on rabbits.

Summing up, it may be stated, however, that the introduction of lipiodol into the air passages only very rarely causes acute or chronic harmful effects of practical importance.

However, many attempts were made to find a contrast medium which would not have the disadvantages, sometimes experienced with lipiodol. A contrast medium soluble in water was sought, notably by ÅKERLUND and his school. They carried out much experimental work, with this object in view. The chief difficulty was to find a suitable preparation with an adequate degree of viscosity.

Since 1948 the firm Cilag, Schaffhausen, Switzerland, has produced Joduron-B, containing 50% Joduron in a watery solution of cellulose-glycollic-acid-ether, which is very viscous. Experience with this new preparation to date, as described in the literature, seems favourable. FISHER states that no trace of this contrast medium could be detected in the lungs by X-ray examination as early as 12 hours after its administration. The disadvantage of Joduron-B, however, is its excessive viscosity. It is true that it can be diluted with saline solution, but this also considerably reduces its opacity. The rapid absorption from the lung of the Swiss preparation, on the other hand, is a great advantage, particularly for bronchography in patients with pulmonary

tuberculosis, because it removes the chief objection of phthisiologists to bronchography The same applies to the bronchographic examination of patients for whom surgical therapy is contemplated

The Swiss communications, therefore, merit serious consideration, but practical experience alone will prove whether or not Joduron-B equals, in all respects, the excellent qualities of lipiodol It is our personal experience that Joduron-B is too viscous, and does not spread easily in the smaller bronchi This is a considerable disadvantage for bronchography in children For the present, lipiodol is certain to maintain its place of honour, as the contrast medium of choice for bronchography

Indications and contra-indications for bronchography

The diagnostic possibilities of bronchography are many A satisfactory filling gives a complete survey of the bronchial tree and the various anomalies existing in it, the dilatation, stricture or occlusion of certain bronchi being clearly visualized When a displacement or a pushing aside of part of the bronchial tree is present, it is possible to arrive at valuable conclusions concerning the nature of the pulmonary lesion and also especially concerning its location inside or outside the lung

Consequently the indications for bronchography are many In all cases where it is desirable to obtain a clear survey of all the bronchi, bronchography is indicated It is indicated, where a suspicion of the formation of intrapulmonary cavities exists, caused either by dilatation of the bronchi (bronchiectasis) or situated in the pulmonary tissue itself (abscess) It is also indicated in patients who have had profuse expectoration for lengthy periods, in cases of unexplained haemoptysis or prolonged dry cough, in cases showing shadows on the routine X-ray picture which are difficult to interpret, or where there is a suspicion of tuberculous bronchitis etc , etc Bronchography is also of the greatest importance, where extrapulmonary conditions such as mediastinal tumours, affections of the pleura etc are concerned The accurate knowledge of the anatomy of the bronchial tree and of the lung segments makes it possible to localize exactly pathological processes in the lung This is very important, especially when surgical therapy is under consideration

It should be borne in mind that a residue of lipiodol may sometimes remain in the lung for months, and for this reason the routine X-ray examination and planigraphy must always precede bronchography

There are a few contra-indications for lipiodol examination, the chief of which are the following:

a *Very poor general condition*, which is easily understood.

b *Pulmonary tuberculosis*, where the process displays evident activity. Various investigators found an unfavourable general and local reaction, sometimes even a miliary dissemination after bronchographic examination in such patients BALLON holds the view that the presence of micro-organisms other than the tubercle bacilli, e.g. pneumococci and haemolytic streptococci, must in some cases be held responsible for this. This is also WEINBERG's view, based on his experiments on rabbits. IGLAUER, KUHN, RAD and others, think that the lipiodol itself is the harmful agent and advocate the use of brominpin or brominol for the contrast examination of patients suffering from pulmonary tuberculosis. They introduce 20 cc of this bromide preparation and never observed unfavourable reactions in tuberculous patients. Of late years, however, a broader view is generally taken about tuberculosis as a contra-indication for lipiodol examination. The results appear to be less harmful than one would expect. However, various publications advocate care, and the indications should be carefully considered

c *Shortly after haemoptysis.* Lipiodol examination made too soon after haemoptysis tends to cause a recurrence of the haemorrhage, due possibly to reactive hyperaemia and also to the frequently severe coughing after the examination It is generally advisable, as practical experience shows, to postpone the lipiodol examination for 8 to 10 days

d. *Acute (purulent) pulmonary process*, e.g. lobar or bronchial pneumonia In these cases, however, the indication for a bronchographic examination will be rare An exception is the pulmonary abscess When this exists bronchography is sometimes indicated, usually, however, only in the subacute stage

e. *Cases where the vital capacity is found to be considerably decreased.* The temporary occlusion of some bronchi by the lipiodol introduced may reduce the respiratory surface available to the patient to an extent which is insufficient for his needs ARCHIBALD and BROWN pointed out that a decrease in vital capacity to less than 50 per cent of the normal value is a contra-indication for bronchographic examination Chronic cardiac defects and serious forms of asthma necessitate great caution

f *Idiosyncrasy for iodine* As has been already discussed this is only

a relative contra-indication ERWIN recommended the use of the corresponding bromide preparation (brompin or brominol) in these cases Bromide preparations, however, are less opaque than lipiodol and do not therefore produce as fine results Moreover, medical preparations can temporarily eliminate the hypersensitivity to iodine of these patients, by means of a preceding desensitizing treatment (antallergan)

g *Thyrotoxicosis* When treating patients suffering from this affection, the introduction of iodized preparations, like lipiodol, should as a rule be avoided Brominol or brompin are the contrast media of choice in these cases

h *Chronic nephritis* The appearance of acute glomerulo-nephritis after the introduction of lipiodol has been described in a few cases (Erlandsson) He considers chronic nephritis, especially in cases where poor excretion exists, a strict contra-indication for bronchography

If the above-mentioned contra-indications are not disregarded, injurious effects resulting from the lipiodol examination of the lungs, as a rule, will be very rarely encountered An accurate and extensive medical examination should, therefore, precede every bronchography, and it should simultaneously be ascertained whether the patient has an idiosyncrasy for iodine or not, by means of the oral administration of a small dose of potassium iodide SCADDING pointed out that the potassium iodide test is not a completely reliable method of testing idiosyncrasy to iodine Often, although this test gives completely negative results, marked allergic phenomena ensue It is always desirable, therefore, to check the cutaneous reaction to tincture of iodine in addition to the potassium iodide test

The various methods of introduction of lipiodol

As a rule the best diagnostic results are obtained from bronchography if the lipiodol is introduced approximately at the level of the larynx It is not necessary to introduce the contrast medium straight into the bronchi or pathological cavities

Anaesthesia Certain precautions should be taken before lipiodol can be introduced The main difficulty is the patient's coughing impulse following the introduction of the contrast medium The cough is a serious factor mitigating against the success of bronchography A considerable quantity of lipiodol is ejected by it from the air passages, while an excessive quantity is forced into the alveoli The cough reflex must, therefore, be eliminated beforehand, if the lipiodol is not

to be prematurely expectorated during or immediately after its *introduction* This is especially important in nervous patients with a highly sensitive reflex.

The majority of investigators use surface anaesthesia for the mucous membrane of the pharynx, the larynx and the large bronchi by means of cocain or a derivative of it This temporarily eliminates the reflexes and the introduction of the lipiodol can be performed with complete ease A few investigators give a sedative in addition, a couple of hours (1 to 2) before the bronchography. This makes the patient quieter during the examination and a smaller quantity of the local anaesthetic is required Some investigators, e g. CORDIER and MOUNIER-KUHN, MYER and BLADES, and ROBIN are satisfied with the preliminary administration of a sedative, with or without a hypodermic injection of atropin to lessen the secretion. If, moreover, good care is taken to warm the lipiodol to body temperature, a careful introduction of the oil excites little or no cough-reflex, thus making anaesthesia of the trachea unnecessary. Perusal of the literature, however, shows that the majority of investigators prefer to use preliminary local surface anaesthesia

Various methods and means of introducing lipiodol into the air passages are practised There is a fundamental difference between the method of introducing lipiodol through the natural passages, either through the nose or through the mouth with or without the help of a catheter, and the injection directly through the cricothyroid membrane. The method of producing the anaesthesia is closely related to the technique employed for the introduction of the lipiodol

Anaesthesia through the nose may be satisfactorily obtained by the method described by HICGUET and HENNEBERT and by FORESTIER and LEROUX At intervals of five minutes, 5 cc of a 1 per cent cocain solution are instilled into the nose three times The patient holds his tongue firmly pulled out, with his head extended at an angle of 45° The first 5 cc cause a severe fit of coughing, the two subsequent doses are inhaled with complete comfort. When this method is employed the anaesthesia is applied through the side of the nose opposite to that of the lung to be examined with lipiodol

If the lipiodol is introduced through the mouth, the anaesthesia is generally performed as follows The base of the tongue, the posterior wall of the pharynx and the palatine arches are sprayed or painted a few times with a cocain solution of 1 to 5 per cent. Subsequently a few cc of a 1 per cent cocain solution are slowly instilled into the larynx by means of a laryngeal syringe, controlled by a laryngeal mirror.

This solution finds its own way through the trachea into the main bronchi, and thus a satisfactory anaesthesia of the whole air passage is obtained within a few minutes CURSCHMANN described a more complicated method, consisting of twice spraying the palatine arches with a 10 per cent cocain solution, while the larynx is anaesthetized by means of a regional anaesthesia of the superior laryngeal nerve with a 3 per cent solution of novocain

As a rule children under eight are given no anaesthetic at all Some investigators, however, e g WIESE and HINDERSEN, use a small quantity of a 2 per cent pantocain solution, while JACOBY and KEATS like PEARSON and THORNTON perform the lipiodol examination on young children by means of a complete avertin-ether anaesthesia[1]

Various authors pointed out that sometimes the patient may be allergic to cocain or its derivatives It is very desirable to determine previously the presence or absence of allergy by means of a cutaneous test, because otherwise, after the intratracheal introduction of the cocain or pantocain solution, serious reactions, even fatal, may occur within a few minutes, due to the rapid absorption by the bronchial mucous membrane

When a satisfactory anaesthesia is effected, the lipiodol can be introduced It should be warmed beforehand, according to SICARD and FORESTIER, to body temperature (95 to 100 degrees Fahrenheit) This has a twofold advantage viz the warmed liquid produces a minimum of irritation during its introduction and the more fluid consistency of the oil permits its more ready diffusion in the small bronchi However this opinion is not held by all BLOCH for instance recommended a temperature of about 75 degrees Fahrenheit He found that this gives a better X-ray picture of the bronchi, as lipiodol at this temperature fills the alveoli less quickly, on account of its greater viscosity

Opinions differ very much in regard to the amount of lipiodol required for a unilateral contrast filling of the bronchial tree SICARD and FORESTIER and many others use 20 cc, but amounts up to 50 cc are used by some However, 10 cc are generally found to be sufficient in most cases When a greater quantity of lipiodol is used, the bronchi, especially those of the lower lobe, tend to become filled to an excessive degree and often in consequence the roentgenograms are not so satisfactory for diagnostic purposes

Lipiodol is spread in the bronchial tree by the force of the gravity and by suction during inspiration For some time a thin even layer of lipiodol remains adherent to the bronchial walls GUNTHER mixed

lipiodol with acacia to form an emulsion, which he considered was more adhesive than lipiodol alone.

The introduction of lipiodol through the natural passages Since the first publications of SICARD and FORESTIER various methods have been evolved by a great number of investigators. These may be grouped as follows

a. The supraglottic methods When this method is employed the lipiodol is usually introduced behind the epiglottis, into the vestibule of the larynx, by means of a syringe fitted with a curved cannula; the procedure being kept under observation in a laryngeal mirror. The patient himself firmly pulls his tongue outwards. This method is employed, among others, by MENDEL, OCHSNER, PRITCHARD and WHYTE, GORDON, HICKEY and FURSTENBERG.

SINGER contents himself with dropping of the warmed lipiodol on the posterior wall of the pharynx The tongue is pulled out and firmly fixed by means of a strip of gauze, thus preventing deglutition. The oil automatically runs into the vestibule of the larynx by way of the pyriform sinus and is thus eventually aspirated, as was shown by VAN GILSE This method is also recommended by MYER and BLADES It has the disadvantage, that some lipiodol nearly always enters the intestinal tract, as a certain quantity remains in the pyriform sinus On the other hand this method is extremely simple and easy. Its chief drawback is that infectious material sometimes present in the pharynx will be carried into the bronchi SINGER's method was used in the Groningen clinic for years with satisfactory results, and was found to be more or less free from drawbacks of any important kind CORDIER and MOUNIER-KUHN employ approximately the same technique They drop the lipiodol on the back of the tongue, a little behind the vallate papillae, about 3/8 inch to the side of the median line In this case the oil also runs down automatically and is subsequently aspirated. It is obvious that the patient must be strictly forbidden to make deglutition movements during the introduction of the lipiodol by these methods.

The pernasal method of introduction is also included among the supraglottic methods This method was described by HICGUET and HENNEBERT, by FORESTIER and LEROUX, and later elaborated by KUDELSKI and others It is based on the principle that when the tongue is firmly pulled out of the mouth, the larynx and epiglottis are pulled up, thus preventing the patient from swallowing. Lipiodol introduced through the nose runs straight along the pharyngeal wall into the larynx A disadvantage is that, here again, infectious secretion

from the nose or the accessory sinuses may be carried into the bronchi along with the lipiodol

It is of interest to note the method described by SGALITZER and NATHAN in 1925, the so-called "Verschluckmethode" (choking method). After a careful anaesthesia of the pharynx and larynx, they told the patient to swallow 50 cc of 40 per cent jodipin. As a result of the "automatic choking", resulting from the deep anaesthesia, part of the contrast oil reached the bronchi. In a later publication, together with BECK, the quantity of jodipin to be swallowed was decreased to 20 cc. OCHSNER also advocated this method, but pointed out the danger of infection from the mouth or pharynx. The great disadvantage of the "Verschluckmethode" was, that a satisfactory filling of the upper lobe bronchi was hardly ever obtained, moreover it was uneconomical and, in view of the rather great risk of infection, was not without danger.

b. The transglottic methods. By these methods the lipiodol is introduced directly into the trachea through the glottis. A special long *curved laryngeal cannula, as constructed by* ROSENTHAL, *is introduced* through the glottis, and this is checked by the laryngeal mirror. The contrast oil is then introduced through the cannula into the trachea and inhaled. This method was recommended by WAMSTEKER and others and was also occasionally employed in the Groningen clinic.

Instead of the cannula a rubber or a semi-rigid catheter is often used with or without a metal olive at the end. This catheter may be introduced either through the nose or through the mouth. If introduced through the nose a rubber catheter (nasal cannula) is used, which automatically finds its way through the glottis when the patient firmly pulls out his tongue with his head extended. This method of using the nasal catheter was proposed by the Belgians HICGUET and HENNEBERT and still has many advocates. If the catheter is directed through the glottis by way of the mouth, it is usually done by means of a curved metal guide, checked by a laryngeal mirror. The guide is then retracted and the catheter remains in situ (CHEVALIER JACKSON, ZAVOD and others). The catheter, usually of calibre Ch. 16, is fixed by means of a strip of adhesive plaster to the cheek, or by means of a perforated rubber stopper held between the teeth (BRDICZKA). GOLDMAN and MAYER use the catheter method, through the catheter (the procedure is observed on the X-ray screen) they introduce a small ureter catheter and try to direct it to a particular part of the lung. In this way they attain what they call "selective bronchography" and are thus able to make serial X-ray films of the

various branches of the bronchial tree. In German literature this method is described as the so-called "gezielte Bronchographie" (directed bronchography). It is, however, a time-consuming procedure and in addition to its advantages it has definite disadvantages, e.g. sometimes an alveolar pseudoabscess or a subpleural infiltration may follow the procedure.

Children under 8 years are nearly always examined by this method. The catheter is usually introduced without any local anaesthesia, by means of a laryngoscope or a laryngeal [illegible] (CHEVALIER JACKSON, LESNÉ and L[illegible]). In the case of children the filling can usually be performed by one of these methods.

Except for young children, the use of a catheter does not offer any particular advantages. With its use the co-operation of the patient is of much less importance, but this seldom presents difficulties in adults. A few disadvantages might be briefly considered. An anaesthetic is introduced unnecessarily into the deeper air passages and there is the possibility of introducing the catheter too deeply. All the lipiodol is then introduced into one particular lung segment, and the considerable local accumulation gives a very massive shadow. This may result in faulty diagnoses. Such excessively deep introduction of the catheter is, of course, a technical fault, but reference to the literature shows that it frequently occurs. An important disadvantage in the use of a catheter is that anomalies of the trachea sometimes escape notice, because the trachea may not be seen or may only be seen in part.

BALLON used the bronchoscope to introduce lipiodol straight into the bronchi. In addition to the bronchoscope a syringe with a very long cannula is required for this purpose. By this method it is possible to fill a selected bronchus with lipiodol and to study its roentgen picture separately. NEIL and GILMOUR pointed out that this may be important in some cases. The advantage of this method is that the secretion present in the bronchial tree can be sucked away before the introduction of the lipiodol. For this method, however, the investigator must be master of the technique of bronchoscopy.

The transglottic method described by IGLAUER, by means of an intubation cannula specially constructed by him, has no great practical value.

The introduction of lipiodol by means of injection through the crico-thyroid membrane. This method was first described by ARMÉ-BR[illegible] and WOLFF. After local anaesthesia of the skin and the subcutaneous tissue of the throat, a thick curved needle or a small trocar is introduced

into the trachea through the cricothyroid membrane. Through this the lipiodol is introduced, preceded by a few cc of a 1 per cent cocain solution to anaesthetize the mucous membrane of the air passages. Some investigators also first inject ½ cc of a 5 per cent cocain solution into the trachea with a fine needle.

This method of introducing lipiodol was first described and recommended especially by the French investigators ARMAND-DELILLE, SERGENT, COTTENOT, FORESTIER, LEROUX, BONNAMOUR and others. ARMAND-DELILLE devised a special injection needle, which is shaped like a normal tracheal cannula and can be fixed in a similar manner after its introduction into the trachea.

It is evident that this method is not completely without danger. LEROUX and BOUCHET, PARADE, HIGGUET and others described as complications: faulty course, injury to the posterior wall of the trachea, edema of the glottis, subcutaneous emphysema, haemorrhage, haematoma and infection along the course of the injection. In skilled hands the risk of such complications is not great, but nevertheless it is on account of them that the method has to a large extent fallen into abeyance. In Great Britain, however, it seems to be regularly employed, e.g. by BROCK.

The spreading of lipiodol in the bronchial tree

This is the result of the force of gravity and of the suction effect of inspiration, as was demonstrated by HUIZINGA and others. POPOVIC also considers that the musculature of the bronchial wall near the carina and the ridges where the lobar bronchi and the segmental branches come off, plays an active part. According to him the filling of the various segmental bronchi largely depends on these factors. This rather original conception is not confirmed anywhere in the literature.

In bronchography the adhesive qualities of lipiodol are utilized. Only a small quantity of contrast medium is used for the examination, and it is spread throughout the whole bronchial tree by a special technique. A thin layer of lipiodol then remains on the bronchial wall for some time. Thus the lumina of the large and of the segmental bronchi remain patent and respiration is only very slightly impeded. When the contrast medium is well distributed, the bronchial wall is therefore covered with a *thin, even, unbroken layer of lipiodol* from the centre to the periphery.

MOUNIER-KUHN performed an exact roentgen examination of the rate at which the lipiodol spreads in the bronchial tree. If the lipiodol

is introduced slowly, various phases may be consecutively observed, which he described as follows

a The passage through the trachea and the main bronchi takes only a few seconds.

b The passage through the lobar bronchi takes a few seconds more. A roentgenogram taken during this phase gives a picture which he compares to a tree in winter, "arbre en hiver".

c As a result of the effect of inspiration and expiration and of the injection of the remaining lipiodol, the smaller bronchi now become visible This occurs after 1 to 2 minutes, depending on the strength of the inspiration and also on the viscosity (temperature) of the lipiodol The roentgenogram now shows the picture of a tree in spring, "arbre en printemps", and it is this picture which provides the most valuable information from a diagnostic point of view in a satisfactory bronchogram and it persists for 3 to 4 minutes

d In the following stage it will be observed that alveolar filling of the peripheral bronchi gradually takes place, again under the influence of respiration and stimulated by the absorption of the alveolar air. MOUNIER-KUHN compares this picture to a tree in summer, "arbre en été" The filling of the alveoli diminishes the visibility of the bronchi, and the roentgenogram of the bronchi at this stage begins to get blurred

On the grounds of his study MOUNIER-KUHN arrived at the conclusion that the finest roentgenograms are obtained about 3 to 4 minutes after the beginning of the lipiodol injection into the trachea

In the main MOUNIER-KUHN's description of the bronchi filling up consecutively with lipiodol is certainly correct, but it chiefly applies to normal bronchi BONNAMOUR and BADOLLE have pointed out that the character of the filling with lipiodol is completely different in an area where diseased bronchi are present The normal alveolar filling does not take place or only takes place to an insignificant degree, because the alveoli in a pathologically changed area are not fully opened up as a rule, due, among other things, to atelectasis, induration due to collapse or pneumonia-like changes, the bronchi usually being filled with secretion The picture of the "arbre en hiver" is characteristic of the bronchogram of such areas As a rule the bronchi in such an area reveal quite a considerable filling with lipiodol, even massive filling being often observed The lack of filling of the alveoli is, therefore, not due to any lack of contrast medium in the bronchi

In contrast to the picture of normal bronchi, which begins to blur after about 4 minutes, that of diseased and distended bronchi, as a

rule, retains the lipiodol for a far greater period of time. BENDOVE and GERSHWIN consider that any bronchus retaining the lipiodol for over 15 minutes is pathological, irrespective of its morphology. They use 20 cc of lipiodol for a unilateral filling and take the roentgenograms as much as 15 minutes later. They are of opinion that in this way they will obtain a clear picture of only the pathological bronchi. Their method certainly has some merit as the diseased bronchi are more or less rendered selectively visible. The drawback is, however, that the localization of these bronchi is not so clear, because the picture of the other branches has in the meantime become completely blurred. For instance, on the right side it will be difficult to make out whether a few diseased bronchi in the lower part belong to the lower lobe area, or whether, in addition or exclusively, the middle lobe area is involved. Generally speaking most authors prefer to take the roentgenograms as soon as possible after the introduction of the lipiodol. Thus the presence and location of pathological bronchi will be most clearly recognized, as all bronchi will be sharply and clearly defined.

If the lipiodol is introduced while the patient is seated, practically only the bronchi of the lowest parts viz. the lower lobes, will be filled. From the diagnostic point of view, however, it is desirable that all segmental branches of the bronchial tree should be filled. As the bronchi run in many various directions, it is necessary to alter the patient's position and attitude during the introduction of the lipiodol, so that each part of the lung is in its turn the lowest, and thus its bronchi can consecutively be filled with lipiodol. The direction of the various bronchi must, therefore, be accurately known to attain a satisfactory filling of all segmental branches.

Most authors make the patient to assume various consecutive attitudes immediately following the introduction of the lipiodol, in such a way that the upper lobe bronchi are filled first and subsequently the bronchi of the lower parts.

The patient who is seated, first leans markedly to the side to fill the upper lobe bronchi, he then leans well backwards and then well forwards to fill the dorsal and ventral branches of the lower and middle lobes with lipiodol. Some authors, e.g. ERWIN, ROBIN, and others prefer to fill the lower lobes first, and subsequently, by means of a change in posture of the patient, the upper lobe bronchi, thus filling from below upwards.

During the introduction of the lipiodol, with the patient sitting on a plain stool, an assistant can direct him to assume the consecutively desired positions. Patients in poor general condition

can be treated lying on an examination table, the assumption of the various attitudes being thus less fatiguing for them In some clinics a table which can be adjusted to various positions is used, and this makes it possible to bring the patient easily and readily into any desired position At the same time this affords the opportunity to affix an apparatus to the table, which makes it possible to follow the course of the filling on the X-ray screen and, if necessary, to correct it. It is evident that in this case the introduction of the contrast medium can only be performed by means of the transglottic catheter method

The value of fluoroscopy during bronchography.

Various American authors are convinced advocates of following *the introduction of the lipiodol in front of the X-ray screen The filling* is thus controlled and at any time when a good picture presents itself, roentgenograms can be made Generally speaking, however, the value of fluoroscopy during the lipiodol examination is overestimated. Gross anomalies are immediately observed, but they are also visible on the X-ray film Lesser anomalies, so important in modern contrast examination, are not, however, so easily detected on the screen Fluoroscopy has even been the source of some misconceptions e g the much discussed presence of bronchial peristalsis, which is probably based on a faulty interpretation of the luminal changes of the bronchi during respiration Observations made during fluoroscopy have a completely subjective character and cannot be checked afterwards They are short momentary impressions, greatly inferior in value to a good bronchogram, the details of which can be carefully studied. As experience shows that the finest X-rays are obtained immediately after the introduction of lipiodol, it is better not to lose time with fluoroscopy

CHAPTER IV

THE ROENTGEN-ANATOMY OF THE NORMAL BRONCHOGRAM

When considering a bronchogram, one is dealing with the projection of the bronchial tree on a flat plane, the roentgen plate Roentgenograms are made of the dorso-ventral, lateral and oblique projections of the bronchial tree

The pictures of the individual bronchi differ considerably in the various projections Thus a dorsal bronchus is clearly seen in the lateral bronchogram, but in the dorso-ventral bronchogram it is not usually very well seen, because it is usually hidden by one ore more of the many ventral bronchi Bronchi which completely overlap in the dorso-ventral bronchogram, are often more clearly seen in the lateral or oblique views As a rule only those bronchi lying parallel to or almost parallel to the plane of the projection are satisfactorily pictured To study the bronchial tree, therefore, it is essential to take roentgenograms in the dorso-ventral, lateral, and oblique positions

An accurate knowledge of the roentgen-anatomy of the normal bronchogram is a fundamental necessity for the bronchographist Without this knowledge it is impossible to understand or to interpret the pathological bronchogram In this chapter the characteristics of the various projections of the normal right and left bronchial trees will be described

The dorso-ventral projections.

The dorso-ventral bronchogram of the right side (fig 31) clearly shows the main bronchus and its continuation, the stem bronchus Of the three lobar bronchi the upper lobe bronchus is the most clearly seen just as it branches off from the lateral side of the main bronchus The middle and lower lobe bronchi can, as a rule, be fairly well seen, although in the majority of cases their shadows partly overlap, because the middle lobe bronchus branches off in the front All of the segmental branches are not clearly visible The apical (1) and the anterior (3) branches of the upper lobe bronchus are excellently

shown, but the posterior branch (2) is not shown so well. *The two* branches of the middle lobe bronchus are often completely or partly projected upon the outline of the lower lobe bronchi and it is difficult



Fig 31 Normal right bronchial tree Dorso-ventral projection

to differentiate them This also adversely affects the picture of the various branches of the lower lobe bronchus Of these only the cardiac (7) and the postero-basal (10) branches are satisfactorily seen The antero-basal (8) and the latero-basal branches (9) often cannot be clearly recognized, because they usually coincide to a considerable extent

with the two branches of the middle lobe bronchus, and not infrequently they partly overlap The important apical bronchus (6) of the lower lobe cannot be examined. It runs a dorsal course and is



Fig. 3[illegible] Normal right bronchial tree Lateral projection

almost completely covered by the pictures of the other bronchi of the lower and middle lobes Its side-branch, running in an axillary *direction* can often be followed in the area between the bronchi of the upper and middle lobes

The dorso-ventral bronchogram of the left side (fig 33) also enables

us to make a good examination of the main bronchus and of the large upper and lower lobe bronchi. The bifurcation of the upper lobe bronchus into its upper and lower divisions is also well seen, but at the same time these bronchi are not projected in quite their true form, as they do not run exactly parallel to the roentgen plate The segmental bronchi of the upper division of the upper lobe bronchus appear to full advantage, only the posterior branch (2)



Fig 33 Normal left bronchial tree Dorso-ventral projection

of the apico-posterior bronchus is less clearly seen. The two branches of the lower division of the upper lobe bronchus, the lingular bronchi (4 and 5), usually coincide to some extent with the basal branches of the lower lobe bronchus, especially with the antero-basal branch, thus preventing a complete survey. As in the right lower lobe, the antero-basal (8) and the latero-basal (9) branches of the left lower lobe bronchus not infrequently partly overlap and thus at times neither of them can be satisfactorily seen. The postero-basal bronchus

(10), the most medial of the three basal branches of the lower lobe, is usually clearly projected The apical bronchus (6) as on the right side, may or may not be clearly shown in part, because it runs in a dorsal direction.

The lateral projections.

A very different picture is presented by the lateral projections. These are of great value when examining the various segmental branches Bronchi running in a dorsal direction are particularly well projected, which contrasts with their unsatisfactory projection in the dorso-ventral bronchogram. As the various branches of the bronchial tree running in a ventral direction are approximately parallel, they are all projected with sufficient space between them to permit of individual examination

In the lateral bronchogram of the right side (fig. 32), the main bronchus and the stem bronchus are well presented Of the large bronchi to the three lobes, the upper lobe bronchus is not visible, but the aperture in the wall of the main bronchus from which it comes off can be clearly seen The middle lobe and the lower lobe bronchi are very distinct. The three segmental branches of the upper lobe bronchus are all clearly visible, and so are the two branches of the middle lobe bronchus The segmental branches of the lower lobe bronchus are also nearly always well presented, especially the apical branch (6). An exception, however, is the cardiac bronchus (7), the projection of which is partly covered by the picture of the three big basal branches, and in consequence only its peripheral parts between the antero-basal (8) and the latero-basal (9) branches are usually visible Occasionally the projections of the postero-basal (10) and the latero-basal branches are seen to overlap

The lateral bronchogram of the left side (fig. 34) does not give a very clear picture of the main and of the upper lobe bronchi The lower lobe bronchus, alone, can be satisfactorily seen The segmental branches of the upper division of the upper lobe bronchus are excellently presented, as are the two segmental branches of the lower (lingular) division It should be noted, however, that the latter two on account of their oblique forward descending courses, are not projected in quite their true form and length, appearing somewhat shortened Of the four segmental branches of the lower lobe bronchus, the apical bronchus (6) as on the right side, is excellently portrayed the three basal branches are nearly always projected sufficiently separated apart to give excellent pictures

From the foregoing it is apparent that a dorso-ventral or a *lateral* bronchogram alone is not sufficient to obtain a well differentiated and complete survey of all the individual segmental bronchi of the



Fig 34 Normal left bronchial tree Lateral projection
(Nr 6¹ is a supernumerary apical bronchus of the lower lobe)

bronchial tree It is always necessary to take both a dorso-ventral and a lateral view, one immediately following the other In consequence, in this way it is not possible to make a complete examination of the bronchial tree on both sides with lipiodol at one sitting, because after the bronchograms of one side have been taken it would not be

possible to take satisfactory lateral views of the other side after the introduction of lipiodol The branches of both sides would be projected overlapping each other, thus presenting a very confused valueless picture When introducing lipidol it is most important to ensure that all of it enters the side to be examined If lipiodol enters the bronchi of the other side, the lateral projection will lose much of its value

In many clinics stereoscopic bronchograms are made The stereoscopic picture thus obtained permits a very fine survey, but it is not much superior to the usual plane projections for diagnostic purposes Moreover it necessitates the use of a special and rather complicated technical apparatus

The oblique projections

As the name "oblique projection" implies, the thorax — and consequently the bronchial tree — is projected on the roentgen plate in an oblique position For this the patient is placed between the roentgen tube and the plate, in a position halfway between that for the dorso-ventral and that for the lateral projections, facing to the right or to the left

Generally speaking, oblique projections are not given the recognition they certainly merit In some cases they are of great value in assessing the nature and extent of anomalies in certain parts of the bronchial tree In the earlier literature on bronchography, oblique views were briefly referred to, by, among others, the Frenchmen SICARD and FORESTIER, as the so-called "positions obliques" The Americans PRITCHARD, WHYTE and GORDON also briefly mentioned them in their publications on the technique of bronchography (1926), without, however, entering into details The scant attention paid to the oblique views by the early investigators is easily explained In the early years of bronchography only unilateral examinations were made almost exclusively A dorso-ventral and a lateral X-rays were taken and these were generally sufficient to make a complete survey of all branches of the bronchial tree of the side examined The need for oblique views was not, therefore, greatly felt In the course of years, however, a change took place, especially when it became more clearly recognized that an accurate diagnosis of the pathological process, as a rule required bilateral bronchography When some authors drew attention to the possibility of performing a bilateral examination at one sitting by utilizing oblique views, interest increased in this method previously little used PIERCE and

STOCKING were the first, in 1937, to discuss the oblique *projections* of the thorax and the bronchial tree in an extensive study.

For this purpose they made use of cadavers, which were first fixed by means of formalin, and subsequently frozen. Serial *sections* were made of the thorax and its contents, in two oblique directions They were 1 to 2 inches in thickness, and roentgenograms were made of

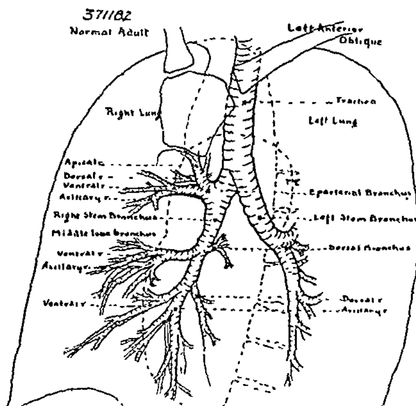


Fig 35a Left anterior oblique projection

Fig 35. The oblique projectio

each separately. These roentgenograms were compared with the anatomical sections and thus they learned something of the roentgen anatomy of the oblique projections of the thorax They also published a separate, rather general description of the roentgen anatomy of the oblique lipiodol pictures (fig 35) Unfortunately they did not mention the angle at which their oblique sections and roentgenograms were made and their diagrams contain some small inaccuracies.

MYER and BLADES (1940) recommended oblique views in two

directions for the complete bilateral contrast examination of patients suffering from bronchiectasis. In their publications they drew attention to the desirability of taking an oblique picture in cases of a unilateral examination, if fluoroscopy makes it clear that lipiodol has accidentally got into the bronchi of the other side ADAMS and DAVENPORT (1942) and ROBIN (1944) are also staunch adt ocates of oblique

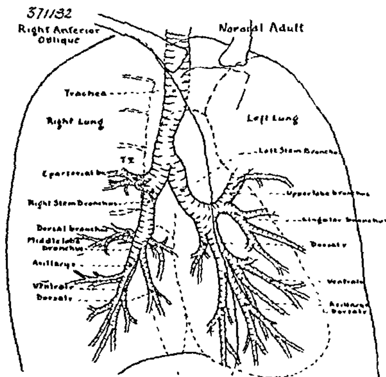


Fig 33b Right anterior oblique projection

...ding to PIERCE and STOCKING)

views They perform the bilateral lipiodol examination of all patients at one sitting They introduce the lipiodol simultaneously on both sides and take one dorso-ventral and two *oblique* X-rays of each patient. In this way they obtain excellent diagnostic results In the new handbook by JACKSON and JACKSON the use of oblique projections in bilateral bronchography is described as practised by them

It is remarkable that in none of the publications referred to, any information is given of X-ray technique in taKing oblique projections,

nor is there any detailed elaboration of the characteristic features of the oblique bronchograms to be found. As an accurate knowledge of these points is of the greatest importance, they will now be more fully discussed

Oblique projections can be made in two positions, viz.

a The patient stands at an angle to the roentgen plate and faces to the left The right half of his thorax is therefore to the front close to the plate The view thus obtained is known as the *right anterior oblique* (= r a o)

b The patient stands at an angle to the roentgen plate and faces to the right The left half of his thorax is therefore to the front close to the plate The view thus obtained is known as the *left anterior oblique* (= l.a o).

The oblique projections are based on the following principle In the ordinary dorso-ventral bilateral bronchograms an area in which no bronchi are visible can be seen between the pictures of the right and left bronchial trees. This area is the mediastinum, occupied chiefly by the heart and the big vessels This makes it possible to take oblique contrast-views up to a certain angle, without the pictures of the right and left bronchial trees overlapping one another. In the oblique projections part of the bronchial tree is projected to a greater extent in the mediastinum In the l a o. position the dorsal branches of the right side and the ventral branches of the left side are thus projected, while in the r.a o the reverse applies. The most predominant feature of the bronchial tree on both sides is its extention anteriorly and laterally, and also that many important branches run obliquely antero-laterally On the right side these are the anterior branch of the upper lobe bronchus, the middle lobe bronchus with its medial and lateral segmental branches, and the antero-basal branch of the lower lobe bronchus with, to some extent, the latero-basal branch. On the left side these are chiefly the left upper lobe bronchus with its lower division and the terminal branches (the two segmental lingular bronchi), the anterior branch of the upper division, the antero-basal branch and to some extent the latero-basal branch of the lower lobe bronchus In our discussion on the lateral bronchogram it was pointed out that the ventral branches, on both the right and left sides, run more or less parallel When examined with lipiodol these bronchi will be most satisfactorily pictured if the patient is so placed that they are parallel to the plate It is evident, therefore, that when the patient is facing to the right (with his left side to the front) the ventral branches of the right bronchial tree will be better presented;

they run approximately parallel to the roentgen plate In this position the ventral branches of the left bronchial tree are not parallel to the plate They lie at a considerable angle to it and are therefore not correctly pictured, appearing shorter than they are in actual fact Conversely, when the patient faces to the left (with the right side to the front) a good picture of the ventral branches of the left bronchial tree is procured, but that of the ventral branches of the right bronchial tree is unsatisfactory

In fig 36 the foregoing is illustrated by means of two diagrammatic

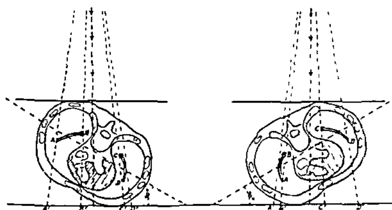


Fig 36 Diagrams of the oblique projections
Left the left anterior oblique projection
Right the right anterior oblique projection

sections of the thorax These two diagrams represent a horizontal section through the thorax at approximately the level of the 7th to 8th thoracic vertebra, in the left and right anterior oblique positions respectively, the angle of rotation being 30 In both halves of the thorax a bronchus has been drawn, AB on the right, CD on the left, representing the course of the ventral branches of the bronchial tree described above The diagram on the left — of the left anterior oblique position — clearly shows the excellent projection of the ventral branches of the right bronchial tree (A_1B_1), the projection of the ventral bronchi of the left bronchial tree (C_1D_1) is very unsatisfactory, the converse is shown by the diagram on the right — of the right anterior oblique position —, the projection C_1D_1 is excellent, but A_1B_1 is considerably compressed

When studying these two diagrams, further points attract our attention In the l a o position the left bronchial tree is to a considerable

extent overlapped by the projection of the spine This is, of course, a great disadvantage The right bronchial tree partly coincides with the cardiac shadow, but this, however, is not a serious matter, as the



Fig 37 Right bronchial tree Left anterior oblique projection

lipiodol gives a very clear contrast, and the hard roentgenograms used in bronchography make it easy to distinguish the bronchi in the cardiac shadow Conversely, in the r a o position the picture of the right bronchial tree partly coincides with that of the spine, and the picture of the left bronchial tree mainly with that of the cardiac shadow. A further disadvantage is that the bronchial tree which is

further from the roentgen plate is better projected in the oblique positions. This results in some slight disproportion if the distance between the roentgen tube and the plate is less than 2 yds and the X-rays are not parallel. If satisfactory oblique bronchograms are to be obtained, it will be recognized that the majority of the bronchi must lie in a plane parallel to that of the plate and they must not be projected on the spine

In addition to the ventral branches of the right and left bronchial trees, all other segmental bronchi are, as a rule, clearly visible individually on the oblique bronchograms The apical bronchus of the upper lobe (1) of the right bronchial tree is well shown in the l a o bronchogram (fig. 37), and its bifurcation into anterior and posterior branches is better seen than in the dorso-ventral view The picture of the posterior branch of the upper lobe (2) is not so good and in most instances it is overlapped by the projection of the trachea and the upper lobe bronchus It is only when it inclines slightly upwards that it is at times reasonably well seen The middle lobe bronchus and its two branches (4 and 5) are shown very well The various basal segmental branches of the lower lobe do not usually overlap and are sufficiently separated to give an excellent projection An exception, however, is provided by the cardiac bronchus (7) Its anterior branch is, in normal cases, projected approximately between the antero-basal (8) and the latero-basal (9) branches The projection of the posterior branch of the cardiac bronchus usually coincides with that of the postero-basal bronchus (10), but sometimes it appears on the medial side of the latter Not infrequently, however, the projection of the cardiac segmental branch completely coincides with that of the latero-basal and postero-basal bronchi, and consequently cannot be distinguished The apical branch of the lower lobe (6) is usually well shown and in contrast to the dorso-ventral bronchogram it is projected apart from the lower lobe bronchus, but its axillary lateral branch, however, is often overlapped by the picture of the stem bronchus, which is a disadvantage

The r a o. view of the left bronchial tree (fig 38) also gives an excellent picture of the apical branch of the upper lobe The posterior subsegmental branch (2) is as a rule not well seen, as it is for the greater part overlapped by the apical branch (1) and is, moreover, very much shortened in its projection, because in this position it is almost at a right angle to the roentgen plate The anterior branch (3) and the two lingular bronchi (4 and 5) are very well shown The basal branches of the lower lobe are almost without exception clearly visible, being

fairly well separated. The apical bronchus (6) is also well shown because, as on the right side, it is projected apart from the lower lobe bronchus

The r a o. view of the right bronchial tree and the l a o. view of the left bronchial tree are as a rule not very important for diagnostic



Fig 38 Left bronchial tree Right anterior oblique projection

purposes, but they are nevertheless certainly helpful because the r a o view of the right bronchial tree (see fig. 43) often gives an excellent picture of the posterior branch of the upper lobe (2) and the apical branch of the lower lobe (6) This is very helpful, because it is just in this respect that the l a o. projection sometimes proves deficient The other branches are not, as a rule, well shown They are

considerably shortened or overlap in their projections and in addition coincide with the shadow of the spine It is noteworthy that in the l a o view of the left bronchial tree (see fig 45), the only branch not well seen on the r.a o view, viz the posterior subsegmental branch (2), is as a rule very well shown The apical branch (1) is also clearly visible, but the anterior branch is not so well seen The remaining branches are projected in an inextricable tangle on each other and on the spine

Both the l a o projection of the left side and the r a o projection of the right side are therefore of definite assistance in the examination of the dorsal branches referred to above These projections possess the great advantage of presenting these branches completely clear of the spine However, it must be stressed again that the r a o view gives the better view of the left bronchial tree and conversely the l a o view gives the better view of the right bronchial tree In routine practice and in discussions with the radiologist the terms "right oblique" and "left oblique" are used to denote the position of the patient which gives the better projection of the bronchial tree to be investigated Accordingly the patient's opposite side is adjacent to the film As "right anterior oblique" and "left anterior oblique" are terms in current use, adopted from cardiology, we have retained them to prevent misunderstanding

From the foregoing the distinctive features of the oblique projections are apparent. On the one hand they display features of dorso-ventral views, while on the other they resemble lateral views It can be stated without exaggeration that not only do they succesfully combine the various features of the dorso-ventral and lateral pictures, but they also give a better survey of an important part of the bronchial tree than do the other two projections To obtain a complete contrast picture *of the bronchial tree of both sides it is, therefore, necessary* to take right and left anterior oblique views consecutively, with a lipiodol filling of the bronchi on both sides Theoretically these two views should be sufficient in all cases, but this is not quite correct For examination of the dorsal branches of the bronchial tree in particular, oblique views are sometimes decidedly inferior to lateral views Moreover it is not possible, as a rule, to localize a shadow in the lung with sufficient accuracy by means of oblique films alone To do so requires two pictures taken at a right angle, a requirement which the *oblique films* unfortunately cannot meet *as has been proved* by experience It is for this reason that in such cases dorso-ventral and lateral views are preferred, because they afford a better means of localizing the shadow more accurately

fairly well separated The apical bronchus (6) is also well shown because, as on the right side, it is projected apart from the lower lobe bronchus

The r a o. view of the right bronchial tree and the l a.o. view of the left bronchial tree are as a rule not very important for diagnostic



Fig 38 Left bronchial tree Right anterior oblique projection

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When taking bilateral bronchograms of the bronchial tree in the oblique positions one is limited to a certain maximum angle It is evident that this angle will decide the diagnostic value of the oblique films If it is too small, the oblique bronchogram will not show any appreciable difference from the usual *dorso-ventral view; if it is* too large, the bronchi of the right and the left sides will partly overlap, thus making their examination difficult or impossible. The angle should, therefore, be such that the projections of the right and left bronchial trees are just barely separated No directions on this point appear in the literature As a result of investigations carried out at Groningen, it was found that the most satisfactory views are obtained if the angle for the right and the left anterior oblique views is on an average 25° for adults and for children. This point will be discussed later, when describing the technique of bronchography in chapter VII.

The following table summarizes the types of pictures obtained of the segmental branches, with the various projections referred to above

Right bronchial tree	Dorso-ventral projection	Lateral projection	Left anterior oblique projection	Right anterior oblique projection
Upper lobe				
1 apical bronchus	good	excellent	good	good
2 posterior bronchus	bad	excellent	bad	good
3 anterior bronchus	moderate	excellent	excellent	bad
Middle lobe				
4. lateral bronchus	moderate	excellent	excellent	moderate
5 medial bronchus	moderate	excellent	excellent	moderate
Lower lobe				
6 apical bronchus	bad	excellent	moderate	good
7 cardiac bronchus	excellent	bad	bad	bad
8 antero-basal bronchus	moderate	excellent	excellent	bad
9 latero-basal bronchus	moderate	good	good	moderate
10 postero-basal bronchus	good	excellent	good	moderate
Left bronchial tree				
Upper lobe				
1 and 2 apico-posterior bronchus — apical branch	good	excellent	good	good
posterior branch	bad	excellent	good	bad
3 anterior bronchus	good	good	bad	excellent
4 *superior lingular* bronchus	moderate	good	bad	excellent
5 inferior lingular bronchus	moderate	good	bad	excellent

Lower lobe				
6 apical bronchus	bad	excellent	bad	good
8 antero basal bronchus	moderate	good	bad	excellent
9 latero basal bronchus	good	good	bad	excellent
10 postero-basal bronchus	good	good	bad	excellent

Variations in the normal bronchogram

When studying bronchograms we find that the pictures may vary considerably, without, however, being pathological In the first place we have cases where anatomical variations exist These are, of course, also seen in the bronchogram A survey of the most frequently encountered variations has already been given in chapter I The bronchograms illustrating this chapter also show some variations from the normal anatomy For instance in fig 32 the apical segment is supplied not by a single apical bronchus, but by two, one branching off from the anterior (3) and one from the posterior bronchus (2) This variation was described by BROCK In fig 34 not only is there a supernumerary apical bronchus of the lower lobe (6_1) but, also the anterior bronchus (3) branches off from the lower division of the upper lobe bronchus This also applies to the bronchogram in fig 38 Anatomical variations in the bronchograms are by no means rare, and are in fact often encountered

The contrast picture of the bronchi themselves may also vary This is particularly striking if one compares bronchograms of the young and old In young persons an excellent uniform filling is usually seen, the lipiodol having penetrated, as a rule, into the finer bronchi far into the periphery ("arbre au printemps", 'arbre en été") Older people do not produce such a smoothly uniform picture. The lipiodol does not penetrate so well into the finer bronchi, and an excessive amount tends to gather in the larger bronchi ("arbre en hiver") It must be assumed that obstructions in the smaller bronchi prevent the lipiodol from penetrating any further and such obstructions are probably caused by the presence of tenacious secretion In addition the weaker and shallower respiratory movements result in a reduced suction force to aid in the distribution of the lipiodol On the other hand, it is sometimes observed that in old people with emphysema the acini of the lower lobes fill to an abnormal extent with lipiodol.

In the roentgenograms of young people the lipiodol is, usually, evenly distributed along the bronchial wall, and the filling shows a uniform continuity from the centre far into the periphery of the bronchial tree In older people the filling is generally less uniformly

distributed, the lining of the bronchial wall apparently varying locally in its adhesive ability The presence of secretion is probably one of the causes, and possibly changes in the bronchial mucous membrane also play a part As a result of chronic inflammatory processes certain changes may occur, for instance the ciliated epithelium may degenerate or disappear, or the mucous membrane may become atrophic or hypertrophic in places

The secretion present in the bronchial tree is an important factor in bronchography The presence of a considerable quantity of secretion may result in failure of the bronchography. Many patients for whom bronchography is contemplated have an inflammatory process in the deeper air passage, and in consequence the bronchi contain secretion to a greater or lesser extent This is clearly evident in the lipiodol picture where numerous interruptions in the lipiodol filling of the bronchi are visible, described by French authors as „les colonnes fragmentées" During respiration the lipiodol and the secretion become mixed and this picture is usually seen in the lower parts of the bronchial tree In some cases the secretion and the lipiodol do not mix, and the latter remains on top of the secretion, thus forming a pseudo-lipiodol stop. These pictures, however, are not seen in the normal bronchogram, and will be discussed in detail in chapter VI.

A distinctive picture may be seen in the normal bronchogram if some bronchi have a more spiral shaped form than usual The projected picture of such bronchi shows a regular crenated form, giving the impression of a pearl-chain These markedly spirally wound bronchi are almost exclusively found in the upper lobe areas In the literature on bronchography we did not find any reference to this picture One should nevertheless be familiar with it, because it may be misinterpreted as bronchiectasis Hitherto it has not been possible for us to carry out an accurate investigation of autopsy preparations in such cases, but in a number of unselected pulmonary autopsies we did not, unfortunately, encounter any case illustrating the foregoing.

If misinterpretation is to be avoided, knowledge of the normal variations to be found in a bronchogram is essential Even with such knowledge it is sometimes extremely difficult to decide whether an anomaly observed represents a variation of the normal or is in fact pathological

CHAPTER V

THE INTERPRETATION OF THE BRONCHOGRAM

The bronchographic examination is not infrequently the ground on which a decision of the greatest importance for the patient is made, e g the decision in favour of lobectomy or pneumonectomy The bronchogram should, therefore, be studied with the utmost care The difficulties presenting themselves in this work are numerous Even the normal bronchogram may present great difficulties in regard to its interpretation, as there may be insufficient or too profuse local filling with lipiodol and not infrequently anatomical variations may be present The simple examination of one bronchogram as a diagnostic procedure is absolutely out of the question nowadays The final interpretation must be the result of a careful comparative study of the different projections of the left and right bronchial trees The interpretation is based on the one hand on an accurate knowledge of the anatomy of the normal bronchial tree and the various segments, and on the other on practical experience which can only be acquired by the frequent performance of lipiodol examinations

As bronchography is intended to furnish information on the localization as well as the nature of a lesion, it is essential that the lipiodol filling should be as complete as possible The bronchial tree must be filled to its outermost limits with lipidol Under such circumstances the projections in various directions give a survey not only of the bronchi themselves but also of their courses in space, which is most important

One of the most important points to be decided when examining a bronchogram is whether all branches of the bronchial tree are present or not The absence of a particular side-branch in the bronchogram may indicate an occlusion, which is very important from the diagnostic point of view Furthermore it is of the greatest importance to determine whether all of the side-branches of the bronchial tree are situated in their normal places A displacement of certain bronchi often supplies vital information for diagnostic purposes Obviously the possibility of the presence of anatomical variations must always be borne in mind Only when one is completely informed with the

roentgen anatomy of the bronchogram, can one proceed to examine and form an opinion on the condition of the various bronchi. The contrast pictures of each bronchus in the different projections must be compared, if an accurate reliable opinion is to be formed of the pathological condition present It is therefore of the greatest importance that the examination of the bronchogram should always be made systematically

In this chapter the case-histories of three patients, two adults and one child, are given briefly Bilateral bronchographic examinations were done on these patients, in accordance with the technique employed at the Groningen university clinic, and which is described in detail in Chapter VII With this technique the bilateral examination is done in one sitting The bronchograms are reproduced here, and are discussed in detail They give a clear picture of the way in which at our clinic the systematic study of a series of bronchograms of a patient is carried out

Figures 39 *to* 46 *inclusive*, are those of a female patient, aged 26 years Her history was as follows. She had been treated for chronic sinusitis since 1934. The various sinuses were repeatedly operated upon, and pus and hyperthrophic polypous mucous membrane were removed She complained of cough since her school days and had "always" expectorated mucoid watery sputum, which occasionally used to become purulent for short periods. During 1943 she was examined in the department of internal medicine. Lipiodol pictures of the right side were taken, and the presence of isolated bronchiectasis in the right middle lobe was discovered Internal therapy met with little success, and her cough and expectoration became worse At the end of 1946 she was hospitalized once more. The possibility of surgical treatment was now considered and she was referred to the oto-rhino-laryngological department for further lipiodol examination

Bronchographic examination A bilateral bronchography was done at one sitting As the previous examination indicated that the right lung was the seat of her trouble, 10 cc of lipiodol were first introduced into the right side and a dorso-ventral and a lateral roentgenogram were made Subsequently 10 cc of lipiodol were introduced into the left side and another dorso-ventral bronchogram was taken and finally the right and left anterior oblique projections were taken at an angle of 25°

The complete series of bronchograms is reproduced here

Fig 39 shows the dorso-ventral bronchogram of the right bronchial

tree. Filling with lipiodol has been very satisfactorily achieved The upper lobe bronchus branches off from the main bronchus in the normal way and trifurcates into the apical (1), anterior (3), and posterior (2) branches, which show no abnormalities. The pictures



Fig 39

of the axillary side-branches of the anterior and the posterior branches more or less overlap and consequently are only partially shown

The middle lobe bronchus branches off from the stem-bronchus in front It bifurcates into the lateral (4) and the medial (5) branches. The lateral branch coincides for the greater part with the bronchi of the lower lobe, but can, nevertheless, be fairly well traced

It shows no abnormalities The medial branch, however, is abnormal It is much too broad, is irregular in shape and is almost massively filled with lipiodol (bronchiectasis).



Fig 40

The five branches of the lower lobe bronchus can all be seen. The apical branch (6) cannot be examined properly, as it is covered for a great part by the lateral middle lobe branch The cardiac branch (7) is very well shown It contains some secretion, but otherwise it is normal The antero-basal (8), latero-basal (9), and postero-basal (10) branches are not projected in a completely free manner. They are

partly covered by the dilated medial branch of the middle lobe bronchus and in addition more or less overlap At the same time the peripheral course can be traced fairly well The antero-basal branch (8) shows no abnormalities In the postero-basal branch (10) the lipiodol has not penetrated as far as the periphery, an interruption is present, probably due to secretion, and the bronchial lumen appears to be slightly dilated The latero-basal branch (9) is not quite normal It contains a massive filling with lipiodol, but despite this the lipiodol does not penetrate beyond a certain point However, this cannot be interpreted with certainty, as its picture partially coincides with that of the antero-basal branch

Fig 40 shows the lateral bronchogram of the right bronchial tree. The trifurcation of the upper lobe bronchus into the apical (1), anterior (3) and posterior (2) branches is clearly seen They are projected completely free and separately One of the peripheral side-branches of the anterior branch does not appear to be quite normal At the peripheral end it appears to be slightly dilated, a small accumulation of lipiodol is visible, which does not penetrate any further

The middle lobe bronchus with its two branches is excellently shown The changes in the medial branch (5), already observed in the dorso-ventral view, show much more clearly (bronchiectasis) The lateral branch (4) is normal

The various branches of the lower lobe are projected completely free, except for the cardiac branch which is partially hidden by the other basal branches The apical branch (6) which cannot be easily traced in the dorso-ventral bronchogram can now be completely surveyed and shows no abnormalities. In the postero-basal branch (10) the lipiodol has penetrated slightly further than on fig 39, this branch contains some secretion, which is probably responsible for the slow penetration of the lipiodol The picture of the latero-basal branch (9) is extremely clear It is full of lipiodol which does not penetrate any further (secretion), in addition the two side-branches are slightly cylindrically dilated The antero-basal branch (8) contains some secretion in its peripheral ramifications

Fig 41 shows the dorso-ventral bronchogram of the left bronchial tree The lipiodol filling of the left bronchial tree is also excellent, all branches being completely filled

The left main bronchus bifurcates into the upper and lower lobe bronchi in the usual way The upper lobe bronchus does not show the normal bifurcation into an upper and a lower division, the anterior upper lobe branch (3) branches off at the site of the

bifurcation, and therefore a trifurcation is present The apico-posterior branch (1 + 2) of the upper lobe can be satisfactorily traced, but its posterior side-branch (2) can only be partly examined. All of these branches are normal The two lingular branches (4 and 5) are excellently



Fig 41.

seen. The inferior branch (5) contains some secretion in the periphery, but apart from this it is perfectly normal.

Of the lower lobe branches only the latero-basal (9) and the postero-basal (10) branches can be satisfactorily examined The antero-basal (8) and the latero-basal branches partly overlap, and the apical branch (6) can only be very incompletely examined. All branches of the lower lobe contain some secretion in the periphery, and some of the side-branches display the picture of "branches cassées" (broken branches). An obvious dilatation, however, cannot be seen

Fig. 42 shows the l.a.o. projection of the right bronchial tree In this view the apical (1) and anterior (3) branches of the upper lobe are well seen It is now evident that the slight abnormality in one of the side-branches of the anterior branch, seen in fig 40, was probabl-



Fig 42

due to the presence of secretion In this view no such picture is seen because the lipiodol has in the meantime penetrated to the periphery The posterior branch of the upper lobe (2) is not well shown, the usual defect of the l a o. view

The middle lobe bronchus and its two branches (4 and 5) are also

of the axis of the bronchial tree, like the anterior branch of the upper lobe, because in this view the bronchial tree is turned 50° to the left as compared with fig 42.

Fig 44, the r.a.o. projection of the left bronchial tree, gives a fine separate picture of all segmental branches in comparison with fig 41.



Fig 45

Even the posterior branch (2) of the apico-posterior bronchus is fairly distinctly traceable, the apical (1) and anterior (3) branches and also the two lingular branches (4 and 5) are excellently shown.

In regard to the lower lobe branches our attention is immediately attracted by the clear picture of the apical branch (6). In the usual dorso-ventral view (fig 41) it was hardly visible. The three large basal

branches, the antero-basal (8), the latero-basal (9), and the postero-basal (10) bronchi are easily traced. When compared with fig. 41 they are observed to be much better separated. Furthermore the lipiodol has penetrated into the peripheral branches. The picture of the "branches cassées" in fig. 41 has almost disappeared, and the peripheral side-branches are absolutely normal, although here and there some secretion can be seen.

Fig. 45 shows the l. a. o. projection of the left bronchial tree. This view is reproduced here for the sake of completeness only. It has little value in the examination of the branches of the left bronchial tree. The only exception is provided by the posterior side-branch (2) of the apico-posterior bronchus of the upper lobe, which is much better shown than in figs. 41 and 44. The apical branch (1) too is well seen, as in the other views. The remaining upper lobe and basal lower lobe bronchi are all projected on each other, so that they form an inextricable tangle. The apical lower lobe branch (6) also forms a part of it and cannot be examined.

Summary. The series of bronchograms of this patient give a complete survey of all branches of the right and left bronchial trees. In the right a considerable dilatation of the medial branch of the middle lobe bronchus is seen. The latero-basal branch of the right lower bronchus is not completely normal. It displays slightly cylindrical dilatation. The left bronchial tree shows no dilated bronchi. Some secretion can be seen in the bronchi of both the right and left sides, particularly in those of the lower parts. The secretion offers a considerable resistance to the penetration of lipiodol into the bronchi. This becomes evident in consecutive X-rays, that which simulates a pathological picture in one film having disappeared in the next one. Taking a complete series of X-rays is therefore of value in this respect, and mistakes in the interpretation of the bronchograms can thus be avoided with greater certainty.

The diagnosis in this patient based on bilateral bronchographic examination was: extensive bronchiectasis of the medial segment of the middle lobe, slight cylindrical bronchiectasis in the latero-basal segment of the lower lobe on the right and bronchitis of the lower lobe bronchi on both sides.

The bronchoscopic examination showed a considerable amount of secretion on both sides, but particularly on the right in the main bronchus. On the right side it proved to come chiefly from the middle lobe bronchus and to a slight extent from the latero-basal and cardiac branches of the lower lobe. On the left the basal branches of the lower

lobe contained several areas of localized secretion. These findings approximately coincided with what was expected from the bronchograms.

In consultation with the internist it was decided to try treatment



Fig 46

with penicillin. During one wee ... was administ ... ly
intra-tracheally. The results ... ever, very
the cough and expectoration ... ered at ...
treatment

Once a ... *scopy* ... Ag ...

found in the right main bronchus, coming chiefly from the middle lobe bronchus and to some extent from the latero-basal branch of the lower lobe No secretion was seen in the bronchi of the left bronchial tree

As her complaints and symptoms persisted, a lobectomy of the middle lobe, combined, if necessary, with a lobectomy of the right lower lobe, was finally advised

The patient was successfully operated upon shortly afterwards (EERLAND) When the operation was performed, the right lower lobe appeared normal macroscopically and in consequence removal of the right middle lobe was considered sufficient.

At present, two years after the operation, the patient is in good condition, and the cough and the expectoration have disappeared Fig 46 shows the bronchogram which was repeated one year after the operation The stump of the middle lobe bronchus (M) is clearly visible. All the bronchi of the upper and lower lobes are quite normal, the left anterior oblique film gives an excellent survey It is also noteworthy how the anatomy has adapted itself to the altered circumstances, arising from the removal of the middle lobe The empty space is now taken up by the anterior and the antero-basal segments

Figures 47 *to* 50 *inclusive*, are those of a male patient aged 27 years From the history it appears that he became ill in 1933, with pleurisy and bronchitis on the left side After a stay of one year and a half in a sanatorium he became ill once again shortly after his discharge In 1937 his sputum for the first time contained tubercle bacilli In 1938 another course of treatment in a sanatorium followed, and the roentgenogram now showed lesions in both lungs The sputum was alternately positive and negative A left-sided phrenic crush did not alter this

In the course of 1939 and 1940 increasing hilar shadows developed on the left side After an unsuccessful attempt to induce a pneumothorax on the left side, thoracoplasty was considered Before this operation was undertaken, however, a bronchographic and a bronchoscopic examination were carried out The left lower lobe bronchus appeared to be considerably narrowed about 1 inch beyond the bifurcation of the main bronchus, and contained purulent sputum

In 1942 bronchoscopy was repeated On the medial wall of the left main bronchus an ulcer was found opposite the point where the upper lobe bronchus branched off, and the entrance of the lower lobe bronchus was considerably narrowed When a bronchoscopic examination was performed at the end of 1946 these abnormalities were still present,

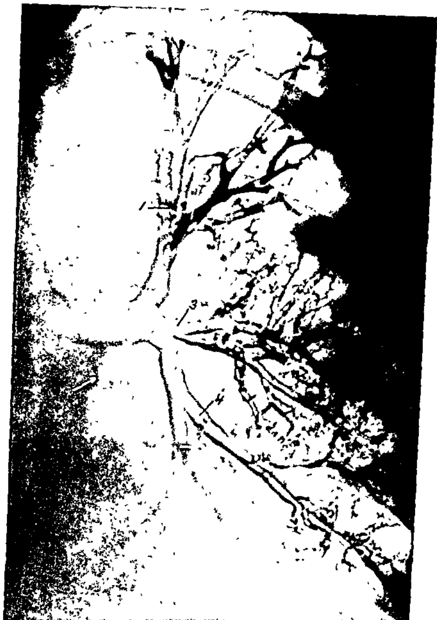


Fig 47.

almost unchanged At the same time a bronchographic examination was made once again A considerably narrowed left lower lobe bronchus was found, and behind it bronchiectatic cavities in the lower lobe which had shrivelled into a small mass. The bronchi of the left upper lobe were normal.

On the basis of these findings a lobectomy of the left lower lobe was considered Before such a procedure could be adopted, it was necessary also to examine the right bronchial tree. We therefore made a bilateral bronchographic examination in Groningen First 10 c c of lipiodol were introduced into the left side and a dorso-ventral and a lateral view were taken Subsequently 10 cc of lipiodol were introduced into the right side and a dorso-ventral view and then the right and left anterior oblique views were taken

The four most important bronchograms are reproduced here and are discussed in turn They are fig 47. left bronchial tree, dorso-ventral bronchogram; fig 48 left bronchial tree, lateral bronchogram; fig 49 right bronchial tree, dorso-ventral bronchogram, and fig 50 right bronchial tree, l a o projection The other bronchograms in this case which were less important for diagnostic purposes — viz the r a o projections of the left and right bronchial trees, and the l a o projection of the left bronchial tree — are omitted.

The dorso-ventral bronchogram of the left side (fig 47) shows an excellent filling with lipiodol It is at once evident that almost all of the left half of the thorax is occupied by the bronchi of the left upper lobe The left main bronchus is normal The usual bifurcation into approximately equivalent upper and lower lobe bronchi is not found here, the left upper lobe bronchus is normal, the lower lobe bronchus on the other hand is considerably narrowed at the point where it branches off The narrowing increases further on in the periphery, and is most marked about ½ inch beyond the bifurcation (arrow). Behind the narrowing a few saccular bronchiectatic cavities are visible The whole left lower lobe has apparently shrivelled into a small medially situated mass, containing a few saccular cavities

The upper lobe bronchus displays the somewhat unusual picture of a trifurcation, the anterior branch (3) coming off at the point where the upper lobe bronchus divides into its upper and lower divisions All bronchi of the upper lobe are larger and broader than normal, due to compensatory expansion The apical (1) and anterior bronchi are normal. The posterior subsegmental branch (2) shows a somewhat massive lipiodol filling, and the margins of the walls seem to be irregular in some places, but this cannot be well examined



Fig 48

in this bronchogram In the lateral view it will be given special attention

The inferior (5) lingular branch of the lower division of the upper lobe is pathological, the lipiodol does not penetrate any further into this branch. The picture is bare and a slight cylindrical dilatation



Fig 49

exists The superior lingular branch (4) is filled in the normal way and, apart from a little secretion, displays no abnormalities

The lateral view of the left bronchial tree (fig 48) completely confirms the abnormalities visible in the dorso-ventral projection. Here too our attention is attracted by the enormous expansion of the upper lobe bronchi It is now evident that the fibrosed lower lobe has shrivelled into a small dorsally situated mass The stenosis of the lower

lobe bronchus is excellently seen (see arrow) with the saccular cavities beyond it

The upper lobe branches are perfectly separated and, *in consequence*, well shown Here, too, the apical (1) and anterior (3) bronchi appear



Fig 50

to be quite normal, the posterior branch (2), however, is pathological Its lowest side-branch gives a bare and massive picture with an irregular, somewhat crenated margin. Towards the periphery the *lumen of this branch does not decrease in the normal way*, but is slightly dilated

The two lingular branches partly overlap, the superior branch (4) is easily traced and is normal, the inferior (5) is not so easily examined It appears that the lipiodol, when compared with fig. 47 has penetrated slightly further into this branch

In the dorso-ventral lipiodol picture of the right bronchial tree (fig 49) we first notice the approximately triangular shadow in the medial area. In it a few smaller and denser round shadows are visible, probably caused by calcified hilar glands

When we view the right bronchial tree superficially, it appears at first sight to be normal, but a systematic inspection, however, shows that this is not so. The upper lobe bronchus branches off in the normal way, its three branches, the apical (1), posterior (2), and anterior (3) show no abnormalities The anterior branch (3), however, descends more steeply than is usually the case

The point where the middle lobe bronchus branches off is not clearly visible. Possibly this bronchus coincides with the branches of the lower lobe bronchus, but an experienced observer immediately suspects that it is completely absent The fact that the branching off and the unfurling of the apical lower lobe branch (6) are so excellently shown, adds to this suspicion A careful inspection informs us that immediately above the opening of the apical bronchus (6) a small mammilliform accumulation of lipiodol exists (see arrow) The middle lobe bronchus is not filled and is apparently occluded

The various basal branches of the lower lobe bronchus are clearly recognizable The cardiac (7), antero-basal (8), latero-basal (9) and postero-basal (10) branches are all normal, although containing some secretion in places. The apical branch (6) is also normal, and its axillary side-branch can be exceptionally well traced

The left anterior oblique projection (fig 50) readily confirms the suspicions raised by the dorso-ventral picture

The absence of the middle lobe bronchus is now very striking Opposite the branching off of the apical branch of the lower lobe (6) a small mammilliform clearance is visible in the front The triangular shadow of the collapsed middle lobe is very obvious in this film. Furthermore the markedly descending course of the anterior branch (3) of the upper lobe and the ascending course of the antero-basal branch (8) of the lower lobe are striking In the periphery the ramifications of these branches almost come together, thus proving that the upper and lower lobes have taken up the space freed by the collapse of the middle lobe.

The apical branch (1) of the upper lobe is well shown, but the

posterior branch (2) is less well seen as is usual in the left anterior oblique *Of the lower lobe* branches particularly the apical (6) and the antero-basal (8) branches are very distinct. The latter contains a considerable quantity of secretion The latero-basal branch (9) is partly covered by the cardiac bronchus (7), the postero-basal branch (10) is very well seen and is normal.

Summary In the case of this patient the following were the findings of the bilateral bronchographic examination. The left lower lobe bronchus is considerably narrowed, and beyond the stenosis there are a few saccular bronchiectatic cavities. The left lower lobe has fibrosed into a small mass situated medially and dorsally The left upper lobe has considerably expanded and occupies approximately the whole of the left half of the thorax. The posterior branch of the apico-posterior bronchus and the inferior lingular branch are obviously pathological and slightly dilated with a somewhat irregular margin of the wall

On the right side the middle lobe bronchus is not seen. At the place where it branches off from the stem-bronchus a mammilliform clearance is visible. The middle lobe has collapsed to a triangular perihilar mass where also a few circular dense spots are visible, due to calcified glands The right upper and lower lobes have occupied the remaining space of the middle lobe. The various segmental bronchi of the upper and lower lobes are normal. In the lower lobe bronchi some secretion is present.

On the basis of the above findings it is easy to understand, why the planned lobectomy of the left lower lobe of this patient was abandoned for the time being In view of the tuberculous nature of the process in the left lower lobe bronchus it was obvious that the possibility of tuberculous bronchitis should be considered as the cause of the changes in the branches of the left upper lobe described above. The fact that these bronchi still appeared completely normal when bronchography was carried out a few months earlier, also pointed in this direction. In that case a pneumonectomy of the left lung might be considered, but before proceeding to this the nature of the process in the right middle lobe had to be more closely examined

The bronchoscopic examination confirmed the findings of bronchography A stenosis of the right middle lobe bronchus appeared to exist The carina of the middle lobe appeared inactive, no granulations being visible It was not possible to obtain tissue for biopsy with the curette and the wall was cicatrized and bled easily In view of the abnormalities in the right lung surgical therapy in this case was eventually abandoned

The bilateral bronchography of this patient illustrates the necessity of always making a bilateral bronchographic examination in cases where the existence of tuberculous bronchitis is suspected This may prevent serious mistakes in establishing the indications for surgical therapy

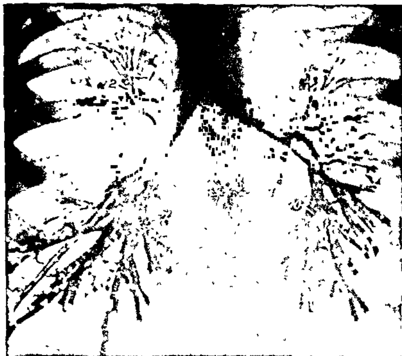


Fig 51

Figures no 51 *to* 53 *inclusive*, are those of a boy aged 6 years It appeared from the history that after bronchitis with pneumonia at the age of two, the boy had continued coughing to a variable extent He only expectorated a little sputum Examination for tuberculosis always gave negative results Eventually he was hospitalized for clinical examination in the children's hospital On the right side a slightly diminished percussion note was heard in front and at the back, most marked in the right lower region posteriorly On auscultation slightly diminished respiration was heard on the right side in front and in the back A few moist and dry rales were also audible,

and in the lower right side posteriorly here and there crepitant rales were heard The sedimentation rate of the red blood corpuscules was 30 mm during the first hour The differential blood count showed a slight leukocytosis and shifting to the left. The ZIEHL-NEELSEN stain of the sputum showed no tubercle bacilli. Von PIRQUET's skin test was negative. On the routine roentgenogram no obvious abnormalities were seen, but the lower areas showed slightly increased striations

After treatment with sulfadiazine for a few days, the sedimentation rate of the red blood corpuscules appeared to have considerably decreased to 12 mm during the first hour. The abnormal physical findings on the right side, however, remained unchanged. As the existence of bronchiectasis was suspected he was sent to our department for lipiodol examination

Bronchographic examination was carried out on this boy in accordance with the method described for children in Chapter VII. 10 cc of lipiodol, 5 cc for the right side and 5 cc for the left side, were *injected without anaesthesia, by means of a catheter, in one movement* The usual series for children's bronchograms was made, viz. one dorso-ventral, one l a o and one r a o. projection (angle of projection 25°) All three pictures are shown here and are discussed in turn

Fig 51 shows the bilateral dorso-ventral projection. The filling with lipiodol is very satisfactory on both sides, all segmental branches are filled. In the right bronchial tree the main bronchus and the upper lobe bronchus are clearly projected. Of the three segmental branches of the upper lobe, the apical (1) and the anterior (3) are well shown, but the posterior branch (2) cannot be completely examined The segmental branches of the middle and lower lobe bronchi overlap, and on account of this they are not seen separately. Only the cardiac (7) branch of the lower lobe can — although rather indistinctly — be traced The other branches together form an inextricable tangle.

It is obvious that the lower lobe bronchi are not normal. The lumen scarcely decreases towards the periphery, and a few branches are, to a small extent, cylindrically dilated. Notwithstanding an abundant filling with lipiodol, it does not penetrate sufficiently. In one place the bronchi are as it were broken off, the picture of the "branches cassées", caused by secretion.

As on the right side, the various segmental branches of the left bronchial tree cannot be examined separately. The bifurcation of the main bronchus into upper and lower lobe bronchi is very indistinct. The upper division of the upper lobe bronchus cannot be traced,

only the segmental final branches, the apico-posterior (1 and 2) and the anterior branches (3), being fairly well projected They show no abnormalities Of the two branches of the lower division of the upper lobe bronchus only the superior lingular branch (4) is separately visible The inferior lingular branch covers the antero-basal branch of the lower lobe bronchus, thus not being completely visible The latero-



Fig 52

basal (9) and postero-basal (10) branches of the lower lobe are fairly well seen

As on the right side, the lipiodol does not penetrate very well into the basal lower lobe bronchi Here, too, some branches give the picture of "branches fragmentées" and "branches cassées", due to the presence of secretion The apical branch of the lower lobe (6) shows no definite abnormalities

Fig 52 shows the l a o projection This bronchogram gives a fine

survey particularly of the segmental branches of the right bronchial tree. In comparison with fig. 51 the various segmental branches of the middle and lower lobe bronchi are projected well apart from one another.

The apical (1) and the anterior (3) branches of the upper lobe bronchus are easily traced, the posterior branch is indistinct, only one of its smaller side-branches being visible between the apical branch and the main bronchus The lateral (4) and the medial (5) branches of the middle lobe bronchus are well separated from the lower lobe bronchi They contain some secretion but are not dilated The basal branches of the lower lobe, the cardiac (7), the antero-basal (8), the latero-basal (9), and the postero-basal (10) branches can all be well seen In the cardiac branch the lipiodol has penetrated further than in fig. 51, and like the antero-basal branch it shows the picture of the "colonnes fragmentées" due to the presence of secretion. They are not, however, clearly dilated The latero-basal and postero-basal branches are certainly pathological. The picture is bare, the peripheral ramifications are not filled, various "branches cassées" are visible and the peripheral branches are too wide. Compared with fig. 51 the lipiodol has not penetrated further towards the periphery. The apical branch (6) is well seen, and is normal.

The left bronchial tree cannot be examined on this bronchogram, the only branch that can be well traced is the posterior branch (2) of the apico-posterior bronchus of the upper lobe, and it shows no peculiarities All other branches overlap and are unidentifiable.

Fig 53 is the r a o. projection This bronchogram gives a very fine picture of the left bronchial tree in particular. All segmental branches are projected completely apart, only the posterior branch of the apico-posterior bronchus is as usual covered by the apical branch (1) The bifurcation of the main bronchus into upper and lower lobe bronchi and the bifurcation of the upper lobe bronchus into its upper and lower divisions are excellently seen on this projection. The superior lingular branch (4) is not completely filled but shows no abnormalities, while the inferior lingular branch (5) contains some secretion The trifurcation of the lower lobe bronchus into the antero-basal (8), latero-basal (9) and postero-basal (10) branches is very distinct Compared with fig 51 the lipiodol has now completely penetrated into the peripheral side-branches. They contain some secretion but the picture of the "branches cassées" has disappeared completely.

The projection of the right bronchial tree as a whole is far less satisfactory than in fig 52. Exceptions are the posterior branch (2) of

the upper lobe and the apical branch (6) of the lower lobe, these two being very well seen Of the basal lower lobe branches the postero-basal (10) and the latero-basal (9) branches are well shown, but the others coincide with the projection of the middle lobe bronchi and cannot be separated from it In this view too the postero-basal and latero-basal branches continue to show the picture of the "branches

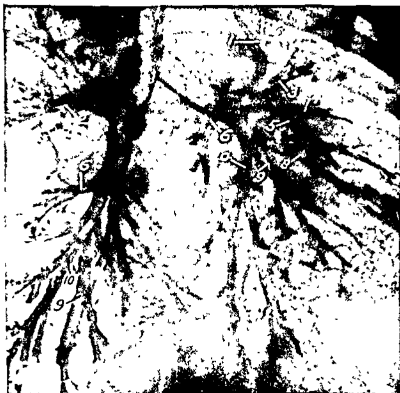


Fig 53

cassées" Compared with the identical bronchi of the left lower lobe they are certainly cylindrically dilated

Summary This boy who has had a cough for years, shows definite abnormalities in the bilateral bronchographic examination On the right side the upper lobe branches are normal, the middle lobe branches contain some secretion but are not dilated Of the lower lobe branches the latero-basal and postero-basal bronchi in particular are cylindrically dilated, the type of the "branches cassées", and all of the other

branches contain secretion. On the left side some secretion is visible in the inferior lingular branch and the basal lower lobe branches, but these are not dilated

The diagnosis of this case must consequently be established as bilateral chronic bronchitis, with a trace of cylindrical dilatation of the latero-basal and postero-basal segmental branches of the right lower lobe bronchus Considering the rather inconsiderable abnormalities and the small quantities of sputum produced daily, surgical therapy was not immediately indicated Possible internal therapy might achieve the desired results.

The lipiodol examination had very remarkable and unexpected consequences for this patient On the day after bronchography his cough had almost ceased and one day later none of the abnormal physical signs on the right or left sides could be detected. The boy was sent home in good condition Should the complaints of coughing and expectoration return unexpectedly, a repetition of the bronchographic examination will determine whether the process in the right lower lobe bronchi is progressive. If the latter should be the case, surgical therapy might be considered in due course.

The series of bronchograms of this patient clearly show the necessity of always taking both oblique bronchograms when examining children with lipiodol They enable us to make an individual survey of all the segmental branches of the right and left bronchial trees, much more satisfactorily than does the dorso-ventral view alone

From a diagnostic point of view the three cases described in detail in this chapter are very interesting for several reasons. In the first place it would have been impossible to establish the diagnosis with certainty without bronchography. Furthermore the importance of the bilateral examination is apparent. Particularly in cases where an operation is considered, the bronchial tree must be examined on both sides Serious errors are thus often avoided.

In the Groningen University Clinic the systematic examination of the dorso-ventral, lateral and oblique projections of every bronchographic examination, as described in this chapter, is always carried out in this manner

CHAPTER VI

THE PATHOLOGICAL BRONCHOGRAM

In Chapter V three short case-histories were given with a detailed study of the complete series of bronchograms They illustrated clearly how the bronchograms of every patient should be systematically examined, and as a matter of fact this is the main principle of bronchography Only thus it is possible to decide with certainty whether the bronchial tree is normal or whether abnormalities are present In a considerable number of cases the examination of the bronchograms helps to establish not only the nature of these abnormalities but also their location The importance of the latter point is obvious because it indicates the sites to which special attention must be given For this reason bronchography should usually precede bronchoscopy as thus a, so-called, directed bronchoscopy can be performed. The exact localization had become more and more important because of the considerable advances made in thoracic surgery, and bronchography is *instrumental in supplying information regarding the parts of the* lung that should be removed, e.g in cases of bronchiectasis

As to the nature of the abnormalities seen in the bronchogram we must bear in mind that bronchography as well as routine roentgen-examination of the lung only give an outline or a silhouette, and that it is seldom possible to establish a diagnosis on the bronchogram alone This can only be done in cases of bronchiectasis, and even then not always because pictures of tuberculous bronchitis sometimes are very similar When a cavity is present in the lung it is, as a rule, difficult to decide without a case-history whether it is a tuberculous cavity, an abscess, or a tumor with central necrosis It is, therefore, advisable, when reporting upon the bronchograms, to describe only the abnormalities present These show little variation and they can all be grouped in the following three categories

1. the dilatation and the formation of cavities in the lung
2. the stenosis and the stop
3. the displacements

In this chapter these three categories will be dealt with in detail. There is really little point in a systematic discussion of all conditions in which bronchography may be instrumental in establishing a diagnosis. We have already referred to the formation of cavities in the



Fig 54

lung, but it will be obvious that an echinococcus cyst will give the same picture in the bronchogram as a dermoid cyst or a teratoma. At the same time many types of peculiarities and differences occur which are valuable for diagnostic purposes

The dilatation and the formation of cavities in the lung.

A great difference exists between the importance of bronchography

in bronchiectasis and in cavity formation in the lung For the former it is a necessity. Originally bronchography was performed almost *exclusively in cases of bronchiectasis and these are still in the majority* Without the use of a contrast medium the diagnosis can seldom be



Fig 55

established with certainty, and this method of investigation has, therefore, become indispensable

In cases of cavity formation in the lung bronchography has little practical importance For the diagnosis of the latter planigraphy has proven itself of the greatest value By means of a series of roentgen-sections through the lung the cavities can be clearly outlined without the use of a contrast medium In addition, the filling of cavities is, as a

rule, difficult, and a negative result is worthless This is due to the fact that cavities, such as a pulmonary abscess, are nearly always filled with secretion and the supplying bronchus is narrowed on account of swelling of the mucous membrane To obtain a satisfactory filling of pulmonary cavities it is usually necessary to use special catheters, such as those of MÉTRAS This is discussed in chapter VII.



Fig 56

On the other hand, bronchography may be of considerable value in accurately localizing a cavity, as illustrated by the following example. A man, aged 47, had developed a fever 11 months previously; a month later cough and sputum appeared An abscess was found in the right upper lobe Conservative therapy resulted in a temporary amelioration of symptoms and the cavity decreased but subsequently increased in size again to a considerable extent. For this reason the patient was sent for surgery

In the ordinary X-ray pictures of the thorax a large cavity with

a fluid level was seen in the right upper area. In the planigrams this cavity was visible in the sections of 4 to 10 cm, being placed porteriorly. It was, therefore, considered probable that it was situated in the posterior half of the right upper lobe, but in view of the great importance of exact localization bronchography was also performed. Figs 54 and 55 represent the dorso-ventral and lateral pictures These show clearly that the abscess was situated exclusively in the right upper lobe, and while it was almost completely confined to the posterior segment it had extended to the apical segment The fluid level (*a*) in the cavity, which was as large as a tangerine, was clearly seen The shadow marked (*b*) is that of lipiodol in the esophagus This is obvious in the dorso-ventral projection but in the lateral (fig. 55) it might easily be mistaken for lipiodol in a pulmonary cavity The axillary branch of the apical bronchus of the right lower lobe (6) is very clearly seen The cardiac bronchus is absent, this is an anatomical variation, and this bronchus is not seen in any of this series of bronchograms The patient was succesfully treated by lobectomy of the right upper lobe

The differential diagnosis of a cavity in the lung and bronchiectasis is not always easy Bronchiectasis might result in abscess formation, on the other hand, an abscess might lead to bronchiectasis The following case is an example of the latter An 8 years old boy had become ill 4 weeks previously with chills He had a high fever and cough An infiltration developed in the right lower lobe with considerable destruction of the tissue A few weeks later there was a copious expectoration of very fetid sputum Investigation with lipiodol showed that large cavities were present in the right lower lobe (see fig 56) Irregular extensions can be seen pointing downwards and extending in the lateral bronchogram deep into the niches behind the dome of the diaphragm The pulmonary abscesses were evacuated by suction through the bronchoscope The secretion quickly diminished, but, naturally, the cavities persisted After some years these had not only become definitely smaller but were also more regular in outline Lipiodol pictures taken on a few subsequent occasions showed after 4 years the condition to be resolved Instead of the large irregular cavities found in the previous dorso-ventral and lateral bronchograms, a considerable number of them can now be seen regularly arranged Particularly in the lateral bronchogram (fig 57) some small lipiodol levels are visible One can only assume that these cavities are newly lined with mucous membrane They are not the result of dilatation of the bronchi, but clinically it is impossible to distinguish

this anomaly from saccular bronchiectasis It is a residual condition following extensive destruction of the lung. In this case the inflammation gradually subsided but a small quantity of secretion continued to come from the right lower lobe bronchus The general condition of the boy is excellent at present. In the lateral bronchogram (fig. 57)



Fig 57

it is seen that the apical and antero-basal segments of the lower lobe are completely normal The cavities are limited to the remaining basal segments

In this case no retraction has taken place and there is no variation in the anatomical structures of the ramifications of the air passages. A study of the various bronchograms strongly suggests that the tension in the surrounding tissues played an important part in the

resolution of the lesion This explains how the diseased lobe gradually underwent change, and the original peculiarly shaped cavities became regular in outline and equably distributed It can only happen in the case of an organ with elasticity such as that of the lung Subsequently, however, such a picture might be considered a typical example of congenital bronchiectasis of the right lower lobe if the history were not known

Congenital bronchiectasis undoubtedly does occur, but it is probably much more rare than is generally considered, particularly by French and German authors, e g DEBRÉ, GILBIN, and SAUERBRUCH In a specific case it is, as a rule, very difficult to decide with certainty The following history may serve to illustrate this

A 33 years old man had had a productive cough since childhood On three occasions he developed pneumonia on the left side Numerous moist rales were audible in the left upper chest The dorso-ventral and lateral bronchograms revealed the presence of a very polymorphous, but chiefly, ampullar and saccular bronchiectasis of the whole of the left upper lobe Otherwise both lungs were completely normal In the dorso-ventral bronchogram the bronchi of the lower lobe gave the picture of "branches cassées", but in the lateral picture a fine alveolar structure was seen everywhere. Circumscribed bronchiectasis of the upper lobe is rare, but still more rare was the fact that with such extensive bronchiectasis there was no trace of retraction to be seen, the mediastinum being normally placed In addition, this man had a bilateral deformity of his ears It is a wellknown fact that congenital deformities frequently occur in multiples

We described the bronchi in the left lower lobe as "branches cassees", broken branches, one of the many clear and eloquent descriptions the French, and particularly MOUNIER-KUHN, have added to bronchography It indicates that the bronchi are to a great extent filled with secretion and, in consequence, the flow of lipiodol is interrupted and the filling is truncated This picture is also very often seen in cases of chronic bronchitis but frequently the bronchi are dilated and cylindrical bronchiectasis exists In the initial stage of bronchography many elaborate descriptions were employed e g "les bronchiectasies *en doigts de gant*" (like the fingers of a glove), "*en grappe de raisins*" (like a bunch of grapes), "en nid de pigeon" (like a doves' nest), "en nid d'aigle" (like an eagles' nest) Many of these names have now lost much of their significance Of course those which refer to, what we might call, the morphology of bronchiectasis continue to be of use Extensive ampullar and saccular bronchiectasis are always irrever-

sible, in contrast to some forms of cylindrical and small ampullar bronchiectasis. Moreover, retention is more apt to occur in large cavities and the sputum is often fetid

It is important to determine at the outset if dilated bronchi are actually present in the bronchogram Generally, this is not difficult because one can make a comparison with the normal bronchi which



Fig 58

are usually present and, moreover, one soon acquires with experience a reasonably accurate impression of what the diameter of the bronchi should be at any particular level. If the diameter of a bronchus is greater than it should be bronchiectasis exists. We only refer to the literal meaning of the word and we see no reasons for using different terminology, as done by some au … in types of bronchiectasis which may … ecede or ev …

The localiza … bronc … especially if surgical thera … idere … significant

since the work of EDWARDS, OVERHOLT, and CHURCHILL has mad it possible to perform segmental resections It has been demonstratec in Chapter V that each bronchus must be checked in a series of bronchograms, thus it can be decided which lobes or segments are diseased Various distributions are possible but, as a rule, bronchiectasis involves adjacent areas e g left lower lobe and lingula, right lower and middle lobes, right lower lobe and the anterior segment of the upper lobe. This is probably due to the fact that the supplying bronchi are more or less subject to the same mechanical factors Many pictures of bronchiectasis illustrating a great variety of locations in the various segments could be produced but this has little value We shall, therefore, content ourselves with only a few cases Often the affection is bilateral, but the left lower lobe is obviously the site of predilection The adherents to the congenital theory attribute this to a disturbance in development due to the position of the heart The following conception, however, appears to be more probable Aspiration (corpora aliena) occurs much oftener on the right side than on the left As it is more difficult to aspirate to the left side it will also be hard to expectorate from this side Therefore, an occlusion by secretion will occur more readily in the left base This often happens in childhood infections like measles or whooping-cough

Fig 58 illustrates an example of bronchiectasis in the left lower lobe and the lingula It is the dorso-ventral bronchogram of a 46 years old woman She had had a cough since she was 3 years of age and expectorated freely Many moist rales were audible at the left base An extensive ampullar bronchiectasis was present in the undersized lower lobe and lingula The bronchiectasis apparently contained a great quantity of secretion and it produced a blotchy, spotty picture This bronchogram is shown here because similar pictures are often seen in cases of tuberculous bronchitis Tuberculosis, however, played no part in this case From the lingula an axillary branch comes off which is normal, as are the anterior and apical segmental bronchi When bronchoscopy was performed it was seen that a great quantity of secretion came from the lower lobe and the lingular bronchi However, it was not possible to operate on this patient because an examination revealed the presence of cardiac and nephritic lesions

Fig 59 illustrates an isolated lingular bronchiectasis in both the superior and the inferior segments It is the dorso-ventral bronchogram of a man, aged 25, who had had symptoms for one and a half years On the left side enlarged hilar glands were found and also a spotte shadow In a lateral X-ray picture the latter was o be loca

in the front half of the thorax and it was thought to be an infiltration. Bronchography made it clear that ampullar bronchiectasis was present in the lingula. When *bronchoscopy was performed no secretion* was encountered. Possibly an occlusion due to pressure of a tuberculous hilar gland was the cause. In our experience, too, bronchostenosis *plays an important* part in the development of bronchiectasis.



Fig. 59

Like most Anglo-American authors we hold the view *that in the* majority of cases bronchiectasis is an acquired affection Bronchiectasis usually develops when a bronchial wall, degenerated following inflammation, is drawn *out by radially operating forces* Pressure from within only plays a secondary part. In the literature, much importance is ascribed to coughing and to the influence of the raised endo-bronchial pressure In coughing, however, the pressure around the bronchi is always higher than the pressure inside them. As has already been discussed in the chapter on physiology, the bronchi become narrower during the act of coughing. There is only one exception *viz*, when by means of a strong movement of the diaphragm,

the air is squeezed from the lower lobes into the upper lobes, and increased aeriation of the tops of the lung is seen on the screen. Bronchiectasis in the upper lobes, however, is rare

Secretion may certainly cause pressure from within LAENNEC, who was the first to describe bronchiectasis, drew attention to this fact. ROKITANSKY compared the origin of bronchiectasis in these cases with the presence of a hydronephrosis behind a uretal stricture

Traction from without can in the first place be caused by respiration. We described in chapter II how during inspiration the bronchial lumen becomes wider on account of the radial traction caused by the expansion of the lung

Atelectasis is an important factor in the origin of bronchiectasis JACOBAEUS and WESTERMARK drew attention to the fact that the considerably raised negative pleural pressure (up to 20 inches of water pressure) displaces the mediastinum and also radially affects the bronchi Atelectasis is nearly always associated with inflammation, and the degenerated bronchial wall yields to this traction If the atelectasis does not recede, induration of the collapsed tissue may follow In the latter condition bronchiectasis will be caused by contraction of the connective tissue (TENDELOO) This type of bronchiectasis is always irreversible Obviously, to all these mechanical factors constitutional factors must be added, as was pointed out by KARTAGENER Many patients are seen in whom the mucous membrane of the whole respiratory tract is diseased They have sinusitis and the bronchi are also degenerated BRONKHORST introduced the term "bronchopathy" to describe this condition

We now know that while many cases of bronchiectasis are irreversible, some cases may recede Probably this is not an infrequent occurrence in acute inflammatory processes of the lungs of children We often observed it after the removal of foreign bodies, bronchography showed bronchiectasis which resolved in a few weeks An example is provided by the following case

A girl, aged 3, had aspirated a peanut into the right main bronchus three weeks previously An obvious obstructive emphysema of the right side was present, and the respiratory sounds were decreased As five days after the removal of the pea-nut the respiratory sounds continued to be diminished, bronchography was carried out Fig 60 was taken on expiration and fig 61 on inspiration It is evident that bronchiectasis had developed in the right lower lobe One should compare these bronchi with the normal ones of the left side



Fig 60



The difference in the two bronchograms is striking The basal bronchi of the right lower lobe are obviously wider in either of them, but in the picture taken on inspiration the bronchiectasis is much more evident.

Eight months later the child returned and bronchography was performed once more The bronchogram showed that the child had completely recovered (fig 62) There was not the slightest difference between the bronchi of the right side and those of the left



Fig 62

When *studying the bronchograms of figs* 60 and 61 it is seen that the diseased bronchi became more dilated during inspiration than did the healthy bronchi A flaccid bronchial wall yields more readily to radial traction In these cases it is often seen how acute bronchiectasis can recover rapidly and completely The wall is certainly inflamed, and it is possible that the dilatation is chiefly due to a loss of tone of the bronchial muscles It would then be an atonic bronchiectasis which may completely recede and can also be called reversible bronchiectasis This condition has also been described by Ochsner, Findlay, Jennings, Fleischner and others

It is quite possible to distinguish *clinically between bronchiectasis* with flaccid walls, which yield more readily to respiration than does the normal bronchial wall, and bronchiectasis with rigid walls resulting *from the* contraction of connective tissue. In the latter case the bronchi show lesser luminal changes than do normal bronchi If one pays *special attention to it, one is* particularly *impressed by the ab-*



Fig 63



Fig 64

normally great changes in the lumen of a flaccid bronchiectasis on respiration Figs 63 and 64 are the dorso-ventral bronchograms of the left lower lobe bronchi of a 5 years old boy. The child had had a cough for a long time, which increased considerably after pertussis-pneumonia 6 months previously The infiltrations were soon absorbed but in the left lower area rales continued to be present *The pictures were taken* during quiet respiration, fig. 63 during expiration and fig 64 during inspiration. The difference is striking, the "branches cassées" in fig 63 have changed into obvious ampullar dilatations in fig. 64

The possibility of spontaneous recovery of bronchiectasis should be thoroughly taken into account when considering the indications for surgery. This is particularly important when dealing with children, as will be illustrated by the following case

A 4 years old boy had had pneumonia 4 months previously which did not completely resolve. Subsequently it turned out to be an atelectasis, which is often mistaken for pneumonia His temperature remained elevated, and at the left base there was considerable dullness and broncho-vesicular breathing The mediastinum was displaced to the

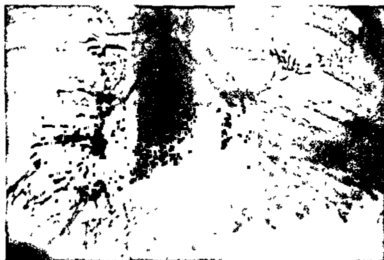


Fig 65

left, and it was thought, that this was due to retraction of the lower part of the left lung It is indeed small as is clearly shown in fig 65 In this bronchogram ampullar bronchiectasis is present, and there is a great difference in comparison with the healthy bronchi on the right side. A lobectomy was seriously considered but when bronchoscopy was performed, however, the left lower lobe bronchi showed no secretion, so it was decided to wait Four years later bronchography was again carried out (fig 66) The left lower lobe had completely re-expanded and the bronchiectasis was cured The diminution of the lower lobe, therefore, cannot possibly have been the result of retraction and it must have been atelectasis The same force (negative pleural pressure) that drew the mediastinum so far to the left in fig 65,

certainly caused radial traction on the diseased bronchi, thus producing the, *fortunately temporary, marked dilatation of the bronchi*

In this case only one lobe was affected but a similar process may be encountered in the whole lung *A boy, aged 1½, was sent to the* pediatric clinic with fever and cough of a few weeks duration He had



Fig 66

extensive pulmonary findings on the left side, viz massive dullness, considerably diminished respiratory sounds, displacement of the mediastinum to the left and marked shadows all over the left lung From the history it appeared that possibly a peanut had been aspirated four months previously. When bronchoscopy was performed a peanut was, in fact, removed from the left main bronchus A great quantity of secretion followed. After that, bronchial breathing and many rales were heard on the left side *The displacement of the mediastinum*

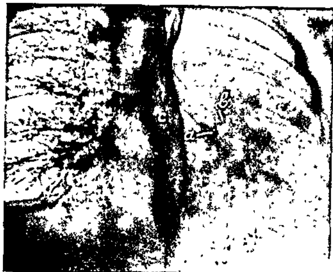


Fig 67



Fig 68

to the left remained, as shown in the bronchogram (fig. 67) made 12 days later. There was considerable ampullar bronchiectasis of the branches of both the lower (*a*) and the upper (*b*) lobes. In view of the prolonged presence of the foreign body a collapse induration associated with retraction seemed probable. After 4 months, however, the dullness on the left side had completely disappeared but rales were still audible.



Fig 69

In the X-ray at that time the left side was considerably clearer, and the mediastinum was in its normal position again. Fig. 68 is the bronchogram made 7 months later. A great difference from fig. 67 is now visible. The topography of the bronchial tree is perfectly normal again, a permanent condition has resulted The bronchi of the left lower lobe are still slightly dilated and here "branches cassées" are present The child continued to cough somewhat and bronchoscopy showed a diffuse bronchitis This is also obvious in the bronchi on

the right side in fig. 68 Repeatedly broken columns of lipiodol are visible, as is often the case when secretion is present Complete resolution has not occurred but a very considerable improvement has taken place The extensive abnormalities seen in fig 67 were, consequently, chiefly caused by atelectasis

It may be difficult to establish the correct diagnosis at a given moment, and to differentiate between atelectasis and retraction A two years old girl became acutely ill with pneumonia on the left side The pneumonia did not resolve and the child was sent to the pediatric department. Dullness on the left side was found with bronchial breathing and many rales, the mediastinum being considerably displaced to the left.

This displacement of the mediastinum is also obvious in the bronchogram (fig 69). In the left lung considerable ampullar bronchiectasis *is present, both in the upper and lower lobes*, and an alveolar structure cannot be seen at all We are impressed by the striking similarity to fig 67, but the further development made it clear that in this case we were dealing with a retraction This was supported by the progressive flattening of the left half of the thorax. Subsequent bronchographies showed that the bronchiectasis steadily extended not only absolutely but also relatively Fig 70 shows the bronchogram made 5 years later. Like fig 69 this X-ray was taken at a tube distance of 2 yds, so that the various organs are pictured in their normal dimensions The changes can thus be objectively expressed in actual measurements In fig 69 the bifurcation lies at 70 mm from the right and 60 mm. from the left wall of the thorax These figures are equivalent to 96 and 70 mm respectively in fig 70 Due to the increasing retraction the mediastinum has been still further displaced to the left The same dilated bronchi can be easily found in both bronchograms One of them has a diameter of 4 mm in fig 69 and of no less than 9 mm in fig. 70. The bronchiectasis has developed much more than has the thorax, as is readily apparent from a superficial survey of both bronchograms This is, therefore, a clear example of bronchiectasis due to retraction The abnormality here is progressive When secretion is present, the obvious therapy in these cases would be pneumonectomy

The ampullar bronchiectasis of this girl has gradually changed into saccular bronchiectasis on account of the increasing retraction In her case the bronchoscopy showed that there was very little secretion and, therefore, surgical therapy was not employed We must bear in mind that the patient's complaints are not the result

of the changes in shape of the bronchi, but are due to the inflammation of the mucous membrane in the same Bronchography produces very impressive pictures and, in consequence, there is a tendency to attach



Fig 70

too much importance to anatomical changes when considering the indications for operation Thoracic surgery is not a form of plastic surgery! The cavities seen, for example, in fig 57 were completely dry. On the other hand dry bronchiectasis may cause profuse hemoptyses necessitating lobectomy or even pneumonectomy.

The classification of bronchiectasis into cylindrical, ampullar and saccular varieties implies that in the latter two types retention may occur sooner or later, and this tends to result in changes in the character of the sputum. The size, and the sometimes irregular shape of the cavities, play some part in this retention, but a factor of great importance is the rigidity of the walls which prevents the collapse of the cavities. After bronchography a residue of lipiodol may persist in these cavities for many days The presence of lipiodol in the free lumen of the dilated bronchi is an entirely different condition from that in which lipiodol is present in the alveoli of healthy lung tissue Expectoration from these rigid bronchi is difficult, probably due to the fact that they do not collapse during the act of coughing This difficulty in expectoration can be particularly well demonstrated in children with unilateral bronchiectasis resulting from retraction After a few coughs it will be observed that the lipiodol has almost completely disappeared from the healthy lung, except for the alveoli where some lipiodol is still present In the diseased bronchi of the other side, however, great quantities of lipiodol can still be seen

Bronchography, in addition to providing definite evidence of dilatation of the bronchi in bronchiectasis, often furnishes further information regarding the nature of the bronchiectasis This can be elicited by taking X-ray pictures on inspiration and expiration and also by taking pictures at *intervals In this way bronchography has contributed much to our knowledge of the origin of bronchiectasis generally* Thus it has been possible to demonstrate in vivo how bronchiectasis can originate or extend as a result of external traction on a bronchial wall degenerated by inflammation The causes of this traction are luminal dilatations associated with the respiratory movements, increased negative pleural pressure due to atelectasis, and contraction of connective tissue Internal pressure caused by accumulated secretion may also be important Consideration of these factors will readily explain *why bronchiectasis tends to develop distally* to a bronchostenosis Here, inflammation is almost always present (in cases of atelectasis without inflammation, bronchiectasis does not develop) and atelectasis results, so if the part of the lung involved does not re-expand a collapse induration will follow with increasing retraction The bronchoscopist sees a number of patients with bronchiectasis distal to a bronchostenosis due to a foreign body or a tumour This association is evident and is generally recognized It is difficult to explain the occurrence of bronchiectasis without obvious bronchostenosis *Bronchiectasis may of course be caused by chronic* bronchitis or

by retraction after an unresolved pneumonia, while some of the cases are congenital. But as a bronchoscopist one gets the impression that in the above mentioned cases also a bronchial obstruction has played a part. This occlusion has disappeared but the result is an irreparable damage The following case serves to illustrate this.

A 9 years old girl had become ill a few months previously with cough and fever There was dullness at the right base and the respiratory



Fig 71.

sounds were diminished As an empyema was suspected an exploratory puncture was performed, with negative findings. During a violent fit of coughing she expectorated a great quantity of sputum In the X-ray picture taken at a tuberculosis centre a triangular shadow was seen in the right lower area, which was typical of atelectasis.

In our department the possible presence of a foreign body was suspected and bronchoscopy was performed at once No foreign body was found but a great quantity of secretion was removed by suction from the middle and lower lobes In the bronchogram taken 2 days later (fig. [illegible] 'ar shadow in the lower part could still be cle[illegible] 'ed the lower and middle lobes. In the lower

lobe an ampullar bronchiectasis was already present, and in the middle lobe there was an alveolar structure which was slightly different from the normal type The alveoli apparently lie close together due to atelectasis, so here too the lipiodol produced dense shadows There are no cavities, however, and the markings are spotty It is an interesting and rare example of a lipiodol filling of a reversible atelec-



Fig 72

tasis The air-containing part of the lung on the right side is supplied exclusively by the upper lobe bronchus (*a*), the upper lobe showing compensatory emphysema Bronchoscopy was repeated and a much smaller quantity of secretion was obtained It appeared from a bronchogram (fig 72), taken 1½ years later, that the middle lobe (*b*) had re-expanded Bronchiectasis had, however, presisted in e greatly diminished lower lobe (*c*)

It would not, therefore, appear too improbable
a plug of recretion lodged in the stem bronchus was

atelectasis of the right lower and middle lobes In processes of this kind the pathological changes in the lower lobe generally persist, an observation we have frequently made. The anatomical structure makes this region somewhat more vulnerable and an accumulation of secretion in the lower lobe bronchi tends to occur more readily. It is also of importance to note that the atelectasis of the middle lobe persisted for a long time after the removal of the secretion. It is probable that the bronchoscopic aspirations prevented the development of bronchiectasis in this lobe, as it obviously happened in the lower lobe We are of the opinion that many bronchoscopists hold the view that bronchiectasis is often caused by an accumulation of secretion or by a swelling of the mucous membrane At a later age this is nearly always irreversible It may be possible to achieve some results with preventive treatment in childhood. Pediatricians should be very much "bronchial obstruction" minded, and the slightest suspicion of a bronchostenosis must be regarded as a definite indication for bronchoscopy

Residual bronchograms

In chapter VII the standard series of bronchograms taken at bronchography were described They are all very important as the bronchial tree is projected in different planes. In addition, it may be important to take several pictures of one particular position during the same procedure. Thus one gets similar films, but, as these are taken at different times, certain details may become more evident in the subsequent X-rays These are the so-called residual pictures They are, so called, by analogy with those of the X-ray examinations of the intestinal tract In bronchography, also, at the time when the residual pictures are taken, some of the contrast medium has already disappeared from the bronchial tree. In X-rays of the intestinal tract the folds of the mucous membrane are much better seen in the residual pictures and often they also show certain structures to greater advantage The mucous membrane of the bronchi too contains folds In the residual picture lipiodol may be seen adherent to irregularities of the surface, e g in defects or protrusions. Thus ulcers, small tumours, granulations, and foreign bodies are better outlined. These residual X-rays might also be termed relief pictures At present they are rarely used in bronchography.

As a matter of fact, the last pictures of the standard series are really the residual ones of the side which was filled first. Great difficulties are often encountered in bronchography because of the presence

of secretion in the bronchi It may happen, for instance, that an incorrect diagnosis of obstruction of a certain bronchus is made on the findings seen in the first pictures, where as, such obstruction is really due to only the presence of secretion Subsequent bronchograms may reveal that the apparent occlusion has disappeared Bronchiectasis and pulmonary cavities are often filled with secretion By placing the patient in such a position that the bronchiectasis or



Fig 73

the cavity are at the lowest point, the lipiodol may take as long as 15 to 30 minutes to get there by gravitation Only then will the abnormality become obvious

In these cases it is important to pay special attention to the position to be adopted by the patient, prior to taking of the residual picture First an effort should be made to fill those parts of the lung specially indicated, and to do so, it is possible to utilize lipiodol already present in the bronchial tree Lipiodol can, for instance, be caused to flow from the large bronchi of one side to those of the other side In the case of a 7 years old boy the pediatric department had diagnosed bronchiectasis of the left lower lobe He had a cough and profuse

expectoration for a long time. At the left base many rales were audible

Fig 73 is the picture taken immediately after bilateral injection of lipiodol. The mediastinum is slightly displaced to the left. The right side is quite normal and all of the segmental bronchi are well filled The right lung shows fine alveolar markings, *"the tree in spring". On* the left side the apical and anterior branches are normal, but in the lingula a diseased bronchus is visible (5) In the cardiac shadow



Fig 74

bronchi can be seen in which the lipiodol only penetrated to a certain level, it has not entered the peripheral branches Fig 74 shows that a further penetration of the lipiodol is actually *impossible. This* picture was taken 15 minutes after that of fig 73 During this time the child had lain on its left side The bronchi of the left lower lobe and the lingula are now *markedly filled with lipiodol but it has* advanced very little further It is a typical picture of "broken bronchi" of the *left lower lobe and the inferior* lingular segment Cylindrical bronchiectasis is present *in the slightly undersized* lower lobe and is apparently filled with much secretion This secretion is also

the cause of the interruptions in the column of lipiodol in the pathological branch of the inferior lingular bronchus

In fig. 74 the lipiodol has almost disappeared from the bronchial tree on the right side The larger bronchi are still slightly outlined,



Fig 75

particularly in the lower lobe which was very well filled in fig 73, and the alveoli still contain lipiodol The lipiodol in the bronchi of the right side has been transferred to the left It will be seen how easily lipiodol can be directed from one site to another This also suggests that transference of secretion can take place, and this in fact does happen It is surprising, therefore, that a specific or a non

specific inflammatory process in the lung can ever remain localized!

Lipiodol can also be transferred from one site to another within the bronchi of the same lung A particular part of the lung can thus be more satisfactorily filled This can be done to any part. It is only necessary to place the patient in such a position that the part of the lung to be filled lies at the lowest point.

The figs 75 and 76 are those of a woman of 29 years of age They are lateral *projections of the right bronchial tree. The first one* was taken immediately after the introduction of lipiodol, the latter after the patient was lying in a prone position for 15 minutes In fig 75



Fig 76

all segmental bronchi are well filled They show an excellent and normal picture, except for the bronchi of the diminished and apparently shrunken middle lobe These bronchi are pathological as a cylindrical bronchiectasis is present, and once more we see the picture of the "broken bronchi" In contrast to the other segments of the middle *lobe no alveolar structure* at all is seen In fig 76 a great part of the lipiodol has been transferred from the healthy bronchi into the diseased bronchi of the middle lobe. The latter are now markedly *filled with lipiodol. The lipiodol has penetrated very* little further but the dilatation of the bronchi is now more obvious

The bronchiectasis depicted in figs 75 and 76 is not the usual post inflammatory bronchiectasis but a *typical specimen* of tuberculous

bronchitis This woman was infected while working as a nurse in a sanatorium, and her sputum had been positive for three years She had "creaky" noises in the chest which signify partial bronchial obstruction, in her case due to tuberculous bronchitis Her temperature was slightly raised Later on pneumonectomy was performed at another hospital, and the diagnosis of tuberculous bronchitis of the middle lobe was confirmed by the pathologist

We have become familiar with tuberculous bronchitis, due particularly to the work of various authors in the U S A It is difficult to define this condition, as every ulcerating tuberculosis is undoubtedly associated with tuberculous bronchi The "bronche de drainage" of a cavity is always infected with tuberculosis We speak of tuberculous bronchitis if the bronchial symptoms dominate the syndrome In such a case there are no obvious cavities, the sputum frequently being positive and often even intermittently negative This positive sputum continues to come from the diseased bronchi for years, as in the case of the above-mentioned patient In the larger bronchi the signs of broncho-stenosis usually predominate In most of the cases of healed fibrous stenosis of a larger bronchus the aetiology is tuberculous Here too, bronchography is very important not only in order to reveal the diseased segmental bronchi but also to localize them accurately This is of significance when surgery is considered

As has already been remarked, the bronchographic picture of tuberculous bronchitis is often difficult to distinguish from ordinary bronchiectasis For a long time pathologists have differentiated between atrophic and hypertrophic bronchiectasis Atrophic bronchiectasis is similar to what is referred to in bronchography as flaccid bronchiectasis, while hypertrophic bronchiectasis is almost identical to the rigid-walled bronchiectasis Tuberculous bronchitis usually gives a blotchy picture Bronchiectasis is present, but the dilatations are often only partially filled and irregular on account of the presence of granulations and caseous material The same picture, however, may be seen in cases of hypertrophic bronchiectasis due to trabeculae and thick secretion The difficulties in the differential diagnosis are illustrated by the following case

A boy, aged 13, had had two haemoptyses The examination for tuberculosis disclosed nothing definite The boy had no cough or sputum Bronchography was performed elsewhere In the dorso-ventral bronchogram (fig 77), taken immediately after the introduction of lipiodol, two abnormalities are visible On the right there is a stop in the cardiac bronchus (7), and on the left the postero-basal bronchus

(10) is dilated The lipiodol does not penetrate any further, the bronchi have irregular endings, and in this area no alveolar structure at all is visible. Either of these abnormalities may be the cause of haemoptysis. The residual picture (fig. 78) determines the location. The stop in the



Fig 77.

cardiac bronchus on the right side has disappeared, and, consequently, it was not a real obstruction but probably a temporary occlusion caused by secretion The course of the cardiac bronchus is perfectly normal. The bronchiectasis in the postero-basal branch on the left side, on the other hand, is still more obvious, and it now contains more lipiodol Bronchoscopy disclosed no abnormalities. The

entrance to the left postero-basal bronchus was clearly seen, and it had a perfectly normal appearance. No secretion came from this bronchus Based on these findings, the diagnosis of non purulent bronchiectasis causing haemoptyses was established A left lower



Fig 78

lobectomy was performed with very good results To our surprise it turned out to be a typical case of tuberculous bronchitis

Residual pictures can also be of importance in differential diagnosis between a stenosis and a stop If the patient is kept in a particular position for some time, the residual X-ray might show that lipiodol has entered the bronchus with a stop seen in the first X-ray So in

such a case there was only a stenosis but not was stop. Sometimes the *contours of a stop* are better outlined in the residual bronchogram.

A woman, aged 42, with a long case-history came to our department. Twelve years previously a *tumour of the left* main bronchus was found by means of bronchoscopy. The *microscopic diagnosis* at that



Fig. 79

time was carcinoma. However, this diagnosis of bronchial carcinoma *was questionable as the patient was still alive after 12 years, with no therapy other than X-ray treatment.* The microscopic examination of a new biopsy established the diagnosis of adenoma. In the meantime the tumour had grown to a large size. Not only was the left main bronchus completely occluded by the growth, but it also filled the whole lower part of the trachea, leaving only a very narrow passage to the right bronchus. The bronchogram (fig. 79) *shows little evidence*

of this It is, nevertheless, a very good picture from X-ray point of view. The segmental bronchi of the right side are all filled, and the tracheal rings are strikingly well marked The atelectasis of the whole left lung is obvious, and both the trachea and the mediastinum are displaced to the left The right lung shows considerable compensatory emphysema, and note should be taken of the apical branch of the lower lobe (6) extending beyond the spine to the left side This is also the case with the branches of the anterior bronchus of the upper lobe (3) These



Fig 80

overlap the site of the tumour, and thus the abnormality under discussion cannot be satisfactorily examined The residual bronchogram (fig 80) is much clearer The lipiodol has disappeared from the protruding side-branches of the right upper lobe The picture appears spotted and not very good, but at the same time the outline of the tumour, which had grown from the left main bronchus far into the trachea, is now clearly visible

In this case the treatment could be no more than a palliative removal of the part of the tumour which protruded into the trachea Fortunately, this brought the dyspnoea to an end and gave much relief The patient died a few years later after a gastric haemorrhage Due to circumstances of war, autopsy could not be performed

The stenosis and the stop.

Bronchostenosis is a frequently encountered lesion. The symptoms found in many pulmonary conditions are often the direct results of it. We know now that in cases of carcinoma and also of tuberculosis



Fig 81

the shadow in the roentgenogram is often entirely or chiefly due to [illegible] lar form [illegible] ore [illegible], a [illegible] negative finding viz., the absence of a stenosis or a stop [illegible]ho-gram, may also provide important diagnostic information

A man, aged 21, had been bedridden with tuberculosis for 2 years.
A definite lesion was present in the left upper chest Tubercle bacilli
were never found A large shadow could be seen in the left upper region,
and a tumour with atelectasis of the left upper lobe was suspected
The patient was sent to our department The triangular shadow in
the dorso-ventral X-ray strongly resembled that of atelectasis of the
left upper lobe Bronchography, however, showed no abnormalities
at all Fig 81 is the dorso-ventral bronchogram All of the segmental
bronchi of the left bronchial tree are present and well filled There is
no trace of a stenosis or a stop to be seen and, therefore, it was definitely
not a bronchial tumour with atelectasis Fluoroscopy and lateral X-rays
disclosed that the lesion was situated in the back of the thorax This
was certainly not consistent with atelectasis of the upper lobe, in
which case the shadow would have been at the front A pneumo-
thorax was induced, but the shadow remained unaltered and it had
a lobate margin It proved to be a neuroma of the mediastinum

Stenosis Bronchography is most important in almost every
form of bronchostenosis Obviously, bronchoscopy, too, should always
be performed Thus it will be possible to determine the nature of the
affection causing the bronchostenosis Microscopic examination of the
biopsy material obtained through the bronchoscope often aids in
diagnosis Therefore, in principle, bronchography should precede
bronchoscopy One thus obtains information about the exact location,
which may be most helpful when carrying out the bronchoscopic
examination When a stenosis is narrow, it is usually impossible to
penetrate beyond it with the bronchoscope In such a case information
about the size and length of the stenosis can only be gained by means
of a contrast medium In addition, it can be seen if a complication,
such as bronchiectasis, has already occurred in the part of the lung
concerned

Bronchography almost invariably reveals the presence of a broncho-
stenosis The nature of the lesion, however, is not so easily ascertained,
because various different lesions often give similar pictures Many
conditions may cause a bronchostenosis The most satisfactory classi-
fication still is VON SCHROTTER's classical scheme, the cause may lie
(a) within the lumen, (b) in the wall, (c) outside the wall

(*a*) This group mainly consists of foreign bodies, blood clots and
secretion The last, in particular is of great practical importance and
has already been sufficiently discussed When the presence of a foreign
body or a blood clot is suspected, bronchography, as a rule, is not
performed In the case of a foreign body the possible consequences are

so serious that bronchoscopy should be carried out first. A fresh blood clot is a contra-indication for bronchography. Experience has shown that the stenosis might disappear spontaneously, and any manipulation which might cause a new haemorrhage should be avoided. We possess a few bronchograms of cases in which, due to accidental



Fig 81

circumstances, bronchography was performed, notwithstanding, the presence of a foreign body or a blood clot. Pictures were obtained that are difficult to distinguish from the ones of group (*b*), which is much more important for bronchography

(*b*). affections of the wall Apart from a number of rare diseases, such as syphilis and lymphogranuloma, the most important lesions are malignant and benign tumours, tuberculosis, swelling of the mucous membrane and undifferentiated granulation tissue.

(*c*). This group, too, is of great practical importance Lesions outside the wall, such as tumours, metastases in the lymphatic glands, tuberculous glands, often cause bronchostenosis

Although in cases of bronchostenosis, one cannot speak of a pathognomonic picture, one can, nevertheless, obtain diagnostic indications from, what might be called, the morphology of the stenosis Affections of the bronchial wall will show as a clearance in the bronchial lumen, whereas those outside the bronchus will cause an indentation of the wall Thus, a contrast arises in the pictures in the bronchograms of intra- and extrabronchial affections With BECTEL and STRNAD we can best classify both conditions into destructive and extending processes When a process is destructive or ulcerating, the clearance in the bronchus will usually have an irregular margin, for example in cases of carcinoma or tuberculosis In case the process is extending, the margin of the clearance will generally be smooth Unfortunately, there are many exceptions to this rule the margin of the large adenoma in figs 79 and 80, for instance, is decidedly irregular Yet, with the necessary caution, we may attach some value to this sign Compression stenosis, as the stenosis due to causes outside the wall is called, always shows a smooth margin, both when the process is destructive or extending Carcinomatous and tuberculous hilar glands generally produce a stenosis with a smooth margin An exception occurs when the process has already grown through the bronchial wall, and has perforated into the bronchus In such a case, one finds an ulceration in the lumen which is difficult to distinguish from an ulcerative primary affection of the wall Fig 82 is a picture of a considerable stenosis with a smooth margin It is an example of a well circumscribed adenoma This patient, aged 30, was sent to our clinic because he had developed a cough 3 years previously and expectorated freely He once had an haemoptysis Although tubercle bacilli were never found in the sputum, the diagnosis of pulmonary tuberculosis was made, and he was in a sanatorium for a long time When attention was attracted by the diminished respiratory sounds on the left side, the patient was sent for further investigation Bronchography disclosed a complete occlussion of the left main bronchus Is was a stop with a smooth margin In view of the large quantities of secretion, the patient was treated by postural drainage for one week A second bronchography, however, showed quite a different picture

In fig 82 a round protuberance is seen arising from the lateral wall of the left main bronchus Along the medial wall a narrow lumen

is still present. This allowed sufficient lipiodol to pass, so that the bronchiectasis which had developed behind the stenosis is well seen The diagnosis of tumour was made on the presence of the spherical protuberance on the lateral wall. This was confirmed by bronchoscopy. The left main bronchus was occluded by a smooth beanshaped tumour, which could be removed completely. The microscopic diagnosis first

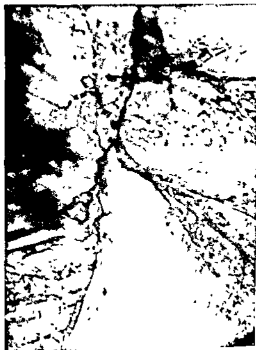


Fig 83

reported was adenocarcinoma Subsequent revision, however, revealed that the lesion was a typical adenoma At present, 22 years later, the patient is still in excellent condition, and there has been no recurrence.

A fundamentally different picture is seen in fig. 83 It is the right lateral X-ray of a man, 48 years of age. Over a year previously, he developed bronchitis and had a troublesome cough Two months ago he expectorated blood X-ray examination showed a shadow with a central cavity at the back of the right lung. Bronchography clearly localized this shadow in the apical segment of the lower lobe. When we studied the bronchial tree, we found that the upper and middle

lobes were perfectly normal, except for a downward displacement of the anterior bronchus and the middle lobe bronchi The middle lobe bronchi supplied a part of the lung resting on the anterior half of the diaphragm Normally, this area is occupied by the lower lobe, and, consequently, the latter was too small in this case The apical branch of the lower lobe bronchus was completely missing in all



Fig 84

bronchograms The dense shadow with the cavity was situated in this segment The lower lobe bronchus was considerably narrowed on account of a protuberance on the back wall, extending from 1 to 2 inches The margin was irregular and crenated in all the bronchograms When bronchoscopy was performed, a tumour was found Biopsy established the diagnosis of carcinoma Following pneumonectomy, the pathologist reported that the cavity was a typical example of a carcinoma with central necrosis.

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In the case of the following patient also, bronchography revealed important information. A man, aged 52, had had a cough for a year with blood stained sputum. For the last few weeeks his temperature was raised at night up to 103° F. In the right lower chest the percussion note was impaired, and the breath sounds were diminished. The X-ray pictures showed a triangular shadow in the right lower area. The mediastinum was slightly displaced to the right, and the hilar shadow was broadened. In fig. 84, the dorso-ventral bronchogram, it is clearly seen that the triangular shadow is due to atelectasis of the right lower lobe in which bronchiectasis is present. The cause is a marked bronchostenosis. In the right main and upper lobe bronchi a lipiodol level is visible, and, apart from compensatory expansion, the upper lobe bronchus is entirely normal. Beyond the branching off of the upper lobe bronchus, the stem bronchus gradually narrows, the walls being smooth. This was confirmed by bronchoscopy; the mucous membrane of the walls was found swollen, and the markings of the cartilaginous rings had disappeared. Contrary to expectation, it was possible to pass the tube through the narrowest part. The latter is clearly seen in the bronchogram, and beyond it the lumen widens. The middle lobe bronchus was normal. The lower lobe bronchus, however, displayed an irregularly granulating wall. This irregularity is also visible in the picture of fig. 84. Biopsy proved this to be carcinoma.

In this bronchogram another important abnormality is seen. The bifurcation is considerably widened. The two main bronchi are markedly pushed apart, as if a large mass were situated between them. This observation was also made at bronchoscopy, the carina being broadened. From these findings, it was concluded that metastases were present in the hilar glands. The broad hilar shadow had already roused similar suspicions. Therefore, the tumour was inoperable. So in this case, the fairly well circumscribed carcinoma in the right lower bronchus had caused large glandular metastases, which were bronchographically demonstrated by the compression stenosis of the stem bronchus and a striking broadening of the carina.

As has been mentioned before, it is not possible to distinguish between the pictures of bronchostenosis caused by carcinoma and tuberculosis. The following case was only decided by bronchial curettage. This is often practised in our clinic when the lesion is located towards the periphery, so that a biopsy cannot be taken by sight. The process is first localized in a particular bronchus by means of bronchography. The entrance to this bronchus is sighted through the bronchoscope, and a small curette, attached to a long handle, is

introduced Usually, a specimen of tissue is obtained, sufficiently large to establish the microscopic diagnosis

A young man, aged 21, had become ill 14 months ago with a fever and repeated haemoptyses At first, no abnormalities were found, but later on there was dullness in the left upper area A dense shadow was seen in the left upper chest, in which cavities had developed These



Fig 85

were interpreted as tuberculous cavities, but repeated examinations for tubercle bacilli were always negative The possibility of a tumour was then seriously considered

The bronchogram (fig 85) shows the triangular shadow in the left apex It is the picture of atelectasis of the apical upper lobe segment n which considerable bronchiectasis exists (B) This atelectasis (the ame picture is seen in cases of fibrosis) is also made obvious by the orizontal course of the left main bronchus The cause of this atelectasis a marked narrowing of the apical bronchus (A) This stenosis has a mewhat irregular margin When bronchoscopy was performed, we

succeeded, notwithstanding the horizontal course of the left main bronchus, to introduce the tube into the upper lobe bronchus. The lingular bronchus was normal; the mucous membrane of the upper division was swollen and hyperaemic. A curette was introduced into the apical bronchus, and microscopic examination of the tissue



Fig 86

removed showed it to be tuberculous A rigid rest-cure resulted in recovery.

Tuberculosis of the bronchial lymph glands may be the cause of an abnormality fairly often noted nowadays, viz fibrous stenosis of a bronchus. In the early stage the swollen glands effect circular compression, particularly of one of the larger bronchi. When a perforation occurs, abundant formation of granulations ensues with destruction of the cartilage of the bronchial wall. Should healing take place, it results, as a rule, in fibrous stenosis This is a serious development,

usually causing bronchiectasis with retention of secretion Often, the lung is also affected with tuberculosis. Among the pneumonectomies performed for tuberculosis, a large percentage have stenosis of a main bronchus.

A woman, aged 25, had become ill with tuberculosis of the bronchial nodes at the age of 14 She had taken the cure for years, and remained symptomless for a long time afterwards, but 1½ years ago her complaints had recurred On one occasion she had a haemoptysis, and complained of dyspnea and wheezing A shadow developed in the right upper chest, which was interpreted as atelectasis The mediastinum was displaced to the right

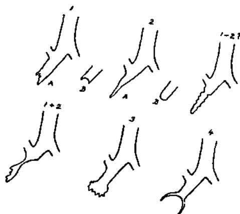


Fig 87

Fig 86 is the dorso-ventral bronchogram The diagnosis of atelectasis is confirmed, the right upper lobe bronchus being completely absent At the site where it should branch off, a considerable stenosis of the main bronchus is present, and the latter has been pulled over to the right Beyond the stenosis, the air passage becomes normal again At bronchoscopy a stenosis was found on the right side, slightly below the bifurcation When it was dilated, one could see that the entrance to the right upper lobe bronchus was completely occluded The diameter of the lumen at the point of the stenosis amounted to no more than 1·5 mm Further dilatations with rubber bougies were carried out on subsequent days For the third treatment a bougie of 17 Charrière was used, and for the ninth treatment one of 22 Charrière The dilatation of these fibrous stenoses generally is difficult and

dangerous. This patient developed an empyema, from which she, fortunately, completely recovered. Eventually the results were satisfactory.

The stop In bronchography a total occlusion of a bronchus is often found, the stop It has been repeatedly remarked that secretion may be an important cause. A real stop must be visible in the complete series of bronchograms In addition, a variable swelling of the mucous membrane is encountered On such occasions, what appears to be a complete obstruction may re-open.

We shall exclusively deal here with the morphology of the stop, *and the conclusions to be drawn from the picture seen in the bronchograms* As in the case of stenosis, these conclusions must be very guarded.



Fig 88

Here too the number of possibilities is not great. They are given in

a rule, show a clearance in the lumen, as indicated by 1. In 1A the margin is irregular, in 1B it is regular. 1A is more suggestive of a destructive process, 1B of an extending one. We *wish to point out*, however, that a stop like 1 B was repeatedly seen, equally well in cases of adenoma, carcinoma and tuberculous granulations.

An occlusion due to compression produces the type of picture seen *in 2A and 2B* The extrabronchial process nearly always attacks concentrically in these cases When the pressure is unilateral, complete occlusion is hardly ever produced, because of the yielding of the

bronchus, but stenosis will result In all cases of compression stenosis, no matter whether a destructive or an extending process is present, the stenosis, as a rule, has a smooth margin In 2A is pictured the lancet, shaped stop, often occurring in cases of carcinoma (see fig 90), in 2B is the round stop, as is frequently seen resulting from the pressure of tuberculous hilar glands

It is, also, difficult to distinguish extra-bronchial destructive processes, growing through the wall, from intra-bronchial ones as pictured in 1—2 in the diagram A similar picture is produced by an extra-bronchial carcinoma growing through the bronchus, and also by an ulcerative process of the mucous membrane Often, a combination of 1 and 2 is seen. In the diagram this is pictured as 1 + 2 A similar stop would be very much suggestive of carcinoma of the stem bronchus with an irregular margin, and higher up a compression due to glandular metastases

Fig 88 shows a typical example of 1A. It relates to a man, aged 52, who 1½ years previously had become subject to periods of fever associated with cough and expectoration At the right base dullness developed with diminished respiratory sounds When bronchoscopy was performed, a cauliflower-shaped tumour was found in the stem bronchus, biopsy showed carcinoma. The bronchogram makes it clear that the triangular shadow beside the heart, which was also seen on the ordinary roentgenogram, is due to atelectasis of the middle and lower lobes All the air-containing lung tissue on the right side is supplied by the bronchus of the upper lobe A stop is present in the stem bronchus, but proximal to it the lumen is normal There is an irregular limitation with a thin offshoot, better seen in the lateral bronchogram These offshoots resembling fistulae are often found in cases of bronchial carcinoma. The post operatively (pneumonectomy) obtained specimen proved to be an endobronchially growing carcinoma, and there were no lesions outside the wall

Fig 89 is of the case of a woman, aged 33, who had had a cough for 6 months, and was hospitalized because of a paravertebral shadow in the right lung The stop is almost at the same site as that of the preceding patient It is for this reason that this bronchogram and the one in fig 88 were chosen from our material. Here, too, the bronchus is normal above the stop, and the oil column ends with a smooth margin (1B) When bronchoscopy was performed, as mooth red tumour was found, the biopsy showing adenoma In 4 sessions the tumour was bronchoscopically completely removed The patient has had no recurrence in 1½ years

Fig 90 is a beautiful example of a compression stenosis. It is the dorso-ventral bronchogram of a man, aged 45, who had pneumonia a few months previously. Since then he had had a cough and blood stained sputum Dullness at the right base was found, with diminished respiratory sounds. The X-ray examination revealed the well-known triangular basal shadow The stop has a completely smooth margin,



Fig 89

the lateral wall protrudes markedly, and the oil column is conical When bronchoscopy was performed, a total occlusion of the stem bronchus was found There was considerable protrusion, especially of the lateral wall The mucous membrane was smooth, with the exception of a few granulating areas The impression was gained that a tumour had grown through the bronchial wall Biopsy showed carcinoma This growth through the wall is not visible in the bronchogram, as it is probably obscured by the dense oil-shadow. Perhaps in a residual bronchogram, which is similar to a relief picture, something

might have been visible, but one was not taken Accidental circumstances afforded the opportunity of performing an autopsy on this patient Here, too, obvious compression stenosis was found, the stem bronchus being compressed by large masses of tumour. Of course the presence of these had also been established roentgenologically,



Fig 90

particularly by planigraphy A stop of this kind always carries a considerably worse prognosis than does a stop like that of the patient in fig 88

The ordinary X-rays of these three patients were similar, they showed the same triangular shadow and compensatory enlargement of the right upper lobe But the stop was different in each case, and it clearly revealed essential differences which gave important information for diagnostic purposes But, as has been said already, the greatest caution should be exercised It is particularly dangerous to

draw conclusions from a single picture alone, and, if this is done, an inaccurate interpretation may be the result. In bronchography projections in various directions are a necessity.

Fig. 91 is the bronchogram of a man, aged 55, who had had a cough and fetid sputum for 6 months. Roentgenologically atelectasis of the middle lobe was found The stop in the bronchus of the middle lobe is conical with an absolutely smooth edge, this may be an occlusion due to compression The stop is so beautifully regular, that without knowing



Fig 91

the history one would be inclined to consider it a developmental anomaly, an agenesis of the middle lobe In the case of an agenesis of a lung, the supplying bronchus may show a corresponding shape. A quite different picture, however, is present in the lateral bronchogram (fig 92) It is not at all a compression stenosis, but the stop has an irregular limitation, and the bronchus does not taper off now In the top part, in particular, an irregular offshoot is seen, and the bronchus is filled much further than it would appear to be from fig 91 Biopsy obtained by curettage from the bronchus of the middle lobe showed carcinoma Pneumonectomy was successfully performed.

An occlusion of the right upper bronchus is frequently encountered. It is a site of predilection for various affections, carcinoma, adenoma, pressure or rupture of tuberculous hilar glands The pictures seen in the bronchogram are often very similar. The diagnosis of obstruction of the right upper lobe bronchus never presents difficulties, in contrast to the left side which will be discussed later. It is a very characteristic picture, the stop is usually clearly visible, and sometimes one is struck



Fig 92

by the fact that the bronchus is completely missing The triangular shadow in the right upper area, due to atelectasis of the right upper lobe, immediately attracts attention This shadow may vary considerably in size, according to whether we are dealing with a pure atelectasis or whether an accumulation of secretion is present in this lobe (the "drowned lung" described by CHEVALIER JACKSON) It also happens that considerable retraction occurs This explains why the lower limitation may run almost horizontally, and in some X-rays even upwards In the latter case the upper lobe is pictured in the roentgenogram as a narrow strip along the trachea The number of

patients with a stop in the right upper bronchus is striking. One example is cited below

A boy, aged 14, who had no complaints at all, had a positive von Pirquet's reaction and a high blood sedimentation rate On examination at a Tuberculosis Centre a marked shadow was reported in the right upper chest, which was immediately interpreted as atelectasis

Fig 93 is the dorso-ventral bronchogram The stop in the right



Fig 93 Fig 94

upper lobe bronchus is clearly seen The steeply ascending side-branches of the apical bronchus of the lower lobe (6) are striking The middle and lower lobe bronchi are projected with considerable overlapping, and, therefore, the various segmental branches cannot be identified with certainty, except for the cardiac (7) and the postero-basal (10). This, however, can easily be done in the left anterior oblique projection (fig. 94) The two branches of the middle lobe (4 and 5) can now be recognized, as also can the three basal bronchi (8, 9 and 10) In this projection the anterobasal bronchus (8) is partly overlapped by the

cardiac, and on account of the atelectasis of the upper lobe the middle lobe bronchus has an abnormally upward course.

If we once more accurately consider the stop in these two bronchograms, we are struck by a few points In the first place it appears from both pictures that the upper bronchus comes off at a remarkably high point, it even branches off mostly from the trachea. The stem bronchus is, therefore, abnormally long The difference in appearance of the stop in the two projections is also remarkable This, once again, illustrates the importance of taking X-ray pictures in various directions In fig 93 the margin is completely smooth, and there is a round stop which is reminiscent of compression as indicated in the diagram of fig 87 by 2B On the other hand, it displays an irregular shape in fig 94 It is a clear example of an irregular limitation of the stop as was indicated by 1A in fig 87. This type is always suggestive of an ulcerating process Bronchoscopy did indeed disclose that the right upper lobe bronchus was occluded by granulations Biopsy showed tuperculosis It was probably a case of a tuberculous hilar gland breaking through into the bronchus

It is seen, therefore, that despite the variety of pictures met with in bronchography, the variations in the shape of the stop are very limited The types with irregular and smooth margins, and the occlusion due to compression are well-known and have been repeatedly discussed in the literature The following types are more rare, but they offer something essentially different and they are represented diagrammatically in fig 87 as 3 and 4 In the former it is indicated that besides the stop a cavity has been formed This points with certainty, in the case of a larger bronchus, to a very destructive process, e g carcinoma, tuberculosis or gumma In such cases the disease causing the stop has also produced considerable dilatation of the bronchus concerned This cannot be explained in any way other than by a slow expansive growth of a benign tumour or a cyst That these possibilities really occur, may be proved by the following two case-histories

A man, aged 65, had become ill a year previously with pain in the right side, and since then he had had a cough and blood stained sputum In the right lower zone a triangular shadow was visible In the bronchogram (fig 95) it appears that the shadow was caused by atelectasis of the lower lobe The bronchi of the upper and middle lobes are filled, the latter probably being compressed at point *a*. At *b* we see the stop in the bronchus of the lower lobe, and medially at *c* there is a cavity with smooth walls The lateral offshoot at point *b*, however, has a notched margin on the medial side When bronchoscopy was performed

the carina appeared to be broadened, a typical sign that the hilar glands were enlarged. The entrance to the upper lobe bronchus was normal, but the bronchus of the middle lobe could only be found with difficulty because the tube entered a cavity lined with red, rough, easily bleeding tissue. Biopsy showed carcinoma. The rough surface



Fig 95

of the walls of the cavity is not seen at all in the bronchogram. Generally, many details can be more easily studied by means of bronchoscopy than by bronchography In this case probably the considerable accumulation of oil, and the resulting dense shadow concealed the irregularity of the wall. It is well known that the stop often seems to be much smoother in the bronchogram than it really is

A man, aged 31, had had repeated haemoptysis for 23 years, sometimes very heavy. The internist found dullness in the right lower base, and roentgenologically there was a dense shadow. The patient was

sent to the clinic The bronchogram (fig. 96) is very remarkable indeed. It appears that the shadow is caused by atelectasis of the lower lobe and a large tumour The bronchi of the upper and middle lobes show nothing special, except the classical compensatory emphysema of the upper lobe The apical lower lobe branch, too, is well filled, as is clearly



Fig 96

seen in the lateral bronchogram In the dorso-ventral projection only its axillary side-branch 6 is visible, as often is the case A remarkable anomaly, however, can be seen There is a stop in the bronchus of the lower lobe, but it is an unusual one The oil runs over a broad basin-shaped mass, like sauce over a pudding On the evidence of this picture, it was presumed that a large tumour had considerably dilated the bronchus This was confirmed by bronchoscopy a round, easily bleeding tumour being found in the dilated lower lobe bronchus

Biopsy showed adenoma. On account of the great dimensions of this tumour, bronchoscopic treatment was of course out of question, and lobectomy was succesfully performed

In the discussion on bronchiectasis we have already mentioned how a better insight into various physiological and pathological conditions has been obtained by bronchography. Patients such as the following, have directed our attention to the conception of collateral ventilation, which is of great practical importance When a lobar bronchus is



Fig 97.

obstructed, atelectasis always occurs, but when a side-branch is occluded, atelectasis does not take place, as collateral ventilation via the stomata in the alveolar walls is possible from those segments which are not involved This has already been discussed in chapter I.

A man, aged 52, had had a cough and sputum for a few months. On the right side of the heart a perihilar shadow was visible, the lower lobe containing a satisfactory quantity of air With bronchography an obstruction of the middle and lower lobe bronchi was shown The bronchograms make it clear that the occlusion of the middle lobe bronchus had led to atelectasis, and this explains the perihilar shadow The pictures also illustrate why, notwithstanding

the complete occlusion of the lower lobe bronchus, no atelectasis has occurred The apical branch remained free, and this made collateral *ventilation possible* As has been shown by experiments on dogs and rabbits, a lobe can be very well ventilated by one large side-branch alone Fig 97 is the lateral bronchogram of the right side In this picture the stop is immediately obvious in the middle and lower lobes,



Fig 98

the apical branch of the latter being completely free The stop has a smooth margin in this projection It was, nevertheless, a carcinoma, as was proven by biopsy obtained at bronchoscopy The tumour was found completely obstructing the lower lobe bronchus beyond the orifice of its apical branch

So in this patient we find that the carcinoma had caused a stop in both the middle and lower lobe bronchi This is very rare It is, of course, possible for a tumour to occlude both the lower and the middle lobe bronchi, but in such cases it usually has grown

into the stem bronchus, or has originated from it. In our large series of bronchograms of patients with bronchial carcinoma we found only a single stop in a large percentage of the cases This applies as much to the large bronchi as to the side-branches. If the carcinoma originates in a segmental bronchus, and the tumour grows very large, the usual finding is that the other bronchi are merely pushed aside Apparently, the growth through the bronchial wall is not rapid We might call this phenomenon: the singularity of the stop

An interesting picture of multiple stops was seen in a patient with lymphogranuloma, a condition in which bronchography is only rarely performed The patient was a young man, aged 21, with multiple swellings of the lymphatic glands. Biopsy, previously carried out elsewhere, had definitely established the diagnosis of lymphogranuloma. Also the biopsies taken from the various bronchi, showed undifferentiated granulation tissue, slightly suggestive of lymphogranuloma There is little doubt, however, that the marked lesion in the lower part of the right lung, which developed during the last few months, was also due to lymphogranuloma. Fig 98 is the lateral X-ray made after the introduction of lipiodol In the lower part on the right an extensive infiltrating shadow can be seen reaching beyond the lobar limits A stop is visible in the middle lobe bronchus. Of the lower lobe bronchi only the apical (6) and postero-basal (10) are filled in this bronchogram. An obvious stop is present in both the antero-basal (8) and latero-basal (9) branches

The absence of a bronchus in the bronchogram.

A stop in the bronchogram is immediately obvious. The proximal part of the bronchus is usually abundantly filled, but the bronchus is cut off more or less abruptly, and this makes a very striking contrast with the normal continuous bronchial picture It occurs, however, that the occlusion is situated at the proximal end of a bronchus, as is seen for instance in the latero-basal branch (9) in fig. 98 This produces pictures which are very difficult to interpret, especially when the part of the lung concerned is collapsed and the space thus available is occupied by other side-branches. In such cases one should search diligently for the stop, which can only be found by an accurate study of the bronchial tree. It should be borne in mind that the fact that a certain bronchus is missing in the bronchogram, may also be due to an anatomical variation Often, however, an irregularity at the site of the stop is found indicating the presence of an abnormality.

Frequently, these cases prove to be the most difficult encountered in bronchography.

A man, aged 63, had had a tuberculous pleurisy on the left side 10 years previously, which healed with considerable calcification A few months ago his cough recurred, but there was no history of sputum or haemoptysis He had lost considerable weight Examination of the


Fig 99



Fig 100

chest showed no abnormal findings In the X-ray a round shadow could be seen at the right side of the heart Bronchography was performed. In the dorso-ventral bronchogram (fig 99) it is clear that all segmental bronchi are filled except the cardiac, which is missing In the left anterior oblique residual bronchogram (fig 100) it appears, however, that lipiodol has enterered this bronchus, and it is slightly dilated with a club-shaped ending in front of the shadow The basal bronchi are well filled, and pass clearly by the shadow Because of the above findings, bronchoscopy was indicated, and special

attention was paid to the cardiac bronchus. A small amount of secretion could be seen coming from this bronchus. The curette was introduced, and thus a little quantity of tissue was obtained. The microscopic diagnosis was carcinoma

Pictures which are difficult to interpret, are encountered when a complete obstruction of the proximal part of the left upper lobe



Fig 101

bronchus has occurred A boy, aged 18, had become ill four months previously, and enlarged hilar glands were found. In the upper part of the left lung dullness developed, associated with bronchial respiration. In the X-ray a heavy shadow was seen which was taken for atelectasis of the left upper lobe In the dorso-ventral bronchogram (fig. 101) the shadow is also visible The trachea has been considerably displaced to the left. Furthermore, a very important sign can be observed, viz the left main bronchus runs much more horizontally than usually. This is strong evidence in favour of atelectasis, at least of a reduction

in size of the left upper lobe. We have already referred to the rule that the bronchial tree is often displaced in the direction of a lesion. When the left lower lobe is diseased, all structures of the bronchial tree run much more vertically, and during bronchoscopy it is then quite possible to look into the lingular bronchus

In the dorso-ventral bronchogram (fig 101) no apparent stop can



Fig 102

be seen, and the ascending branch could be mistaken for the bronchus of the upper lobe An experienced observer, however, would at once recognize that such could not be the case In the normal bronchogram the upper wall of the left main bronchus passes with a gentle curve into the upper lobe bronchus, as does the lower wall into the bronchus of the lower lobe In fig 101 the upper wall suddenly stops at the ascending bronchus This bronchus clearly arises from a circular opening, and it is the ascending side-branch of the apical (6) bronchus of the lower lobe In this bronchogram, therefore, bronchi of the lower

lobe only are filled. This becomes immediately apparent when studying *fig.* 102, the lateral projection. The upper lobe reduced in size by atelectasis, is situated anteriorly, and none of its bronchi are filled. The large apical lower lobe branch (6) with its ascending side-branch are clearly seen. It can now be understood how the picture of fig. 101 resulted when the dorso-ventral projection was taken. The branching



Fig 103

off of the apical lower lobe bronchus must be seen as a circular ostium The smooth round stop, caused by the tuberculous hilar gland which had penetrated into the upper lobe bronchus, is indicated by an arrow in fig. 102

The picture of fig 101, which we have learned to recognize as typical of an occlusion of the proximal end of the upper lobe bronchus, is not extremely rare A man, aged 40, had had a productive cough for 2½ years, and on a few occasions he had a slight haemoptysis A creaking

wheeze developed in the left chest. At a tuberculosis clinic dullness was found in the left upper area, with dimished respiratory sounds. The roentgenogram showed a definite shadow, the mediastinum being displaced to the left At first tuberculosis was suspected, but the sputum was repeatedly reported to be negative

In the bronchogram (fig 103) a similar picture is seen as in fig 101



Fig 104

Here, too, we encounter a misleading picture, due to the fact that a de-branch of the apical lower lobe bronchus markedly ascends cause of the compensatory emphysema of the lower lobe This anch has also strikingly increased in size The apical segmental onchus (6) shows the normal trifurcation, branch (B) supplying axillary part of the lung, branch (A) ascending, and branch (C) cending The stop in the upper lobe bronchus is completely covered the ramifications of the ascending side-branch Here also the

discontinuation of the upper wall of the main bronchus is obvious On account of the atelectasis of the upper lobe this bronchus has a markedly *horizontal course*. Bronchoscopy revealed the presence of a smooth red tumour in the left upper bronchus, and it was removed as far as possible. The pathologist reported that it was an adenoma.



Fig 105

Fig 104 shows the bronchogram made after bronchoscopy had been carried out. The upper lobe bronchus has been reopened, at least to some extent. The apical branch (1) is well filled, and the upper wall of the main bronchus passes into the upper division with a gentle curve. The remaining upper lobe branches are still occluded. The side-branches A, B and C of the apical lower lobe bronchus are now seen being more in the background. In this case the adenoma had developed in the upper lobe bronchus, and probably extended extrabronchially. Therefore, it was impossible to remove the tumour completely by means of bronchoscopy. Consequently, recurrences repeatedly took place Surgery was proposed but was rejected for the time being.

The opposite of the last two cases is shown in fig. 105. Here a com-

plete obstruction at the proximal end of the lower lobe bronchus is present, which is also not obvious It is the dorso-ventral bronchogram of the left side of a 63 years old man He had had a productive cough for 25 years, which had increased during the last year There was dullness in the left lower half, and the X-ray revealed the mediastinum to be displaced to the left A triangular shadow was visible in the cardiac shadow, apparently due to atelectasis of the lower lobe.

In the bronchogram (fig 105) only the upper lobe bronchi are filled At the site of the occlusion of the lower lobe bronchus a lipiodol surface is visible The main bronchus descends markedly The medial wall ought to pass smoothly into the lower lobe bronchus, but near the curve (indicated by an arrow on the bronchogram) an abrupt stop is present In this picture the lingular bronchus might easily be mistaken for the lower lobe bronchus The atelectatic lower lobe occupies very little space, and the upper lobe displays compensatory emphysema Bronchoscopy disclosed a tumour of the lower lobe bronchus, and it was a carcinoma During the bronchoscopy it was easy to look into the lingular branches, this is also evident from the appearance of the bronchial tree in fig 105 Here, too, the bronchial tree has been displaced in the direction of the lesion, in this case medially and downwards ("mouvement de l'horloge") The alveoli are markedly filled, this may be considered as a result of the compensatory emphysema An abundant filling of the alveoli is frequently present in such cases

It has already been remarked that similar pictures are often seen when the occlusion is situated at the proximal end of a lobar bronchus They almost convey the impression that the passage to the remaining normal bronchi is kept free as long as possible, but it could scarcely be possible that the force of the flow of air could prevent further growth of a tumour

Displacements

a *The displacements due to the reduction in size of certain parts of he lung* One of the most important discoveries made by broncho-raphy has been the fact, that considerable changes in pulmonary opography may exist, which cannot be demonstrated by routine X-ray amination These are the marked displacements due to the collapse one, or on the right side of two lobes The phenomenon of the llapse of a whole lung has been known for long, but much time psed before it became generally known that collapse of a lobe also en occurs It may be so considerable, that the space occupied by the

lobe is only a small fraction of the normal size Here, too, particularly roentgenologically, the signs of reduced volume at the diseased side can be seen (displacement of the mediastinum, high position of the diaphragm), but they are by no means so marked as in the case of a collapse of the whole lung. The space normally occupied by the reduced part, is taken up by the tissues of the remaining lobes (compensatory emphysema), thus resulting in a considerable change in the topography of the bronchial tree. The possibilities are almost unlimited, e.g. it may happen on the right side that part of the lower lobe is situated in the apex, and, conversely, a great part of the diaphragm may be covered by the upper lobe

A collapsed lower lobe usually contracts to a small paravertebral area. In the roentgenogram this may be seen as a distinctly limited triangle, on the right side beside the cardiac shadow, and on the left inside it. This triangular shadow is frequently observed. The roentgenological picture was first described by CHAUFFARD, DEVIC, and SAVY, and for a long time this, so-called, triangle of CHAUFFARD was considered typical of mediastinal pleurisy. It would appear, in fact, that this triangle might occur in such cases, but it has, however, never been seen in our clinic We know now that it usually indicates the presence of a collapsed lower lobe, and on the right side even of both the lower and the middle lobes This condition can only be recognized by means of an examination of the bronchial tree with a contrast medium Thus one can distinguish with certainty the bronchus or bronchi which supply the collapsed part

It is remarkable that this important and frequent abnormality was first observed clinically as a result of lipiodol examination, but not in the autopsy room It is, however, difficult at a post mortem examination to determine whether the topography of the bronchial tree is altered, unless special attention is paid to it and the bronchi are cut open

As a rule, bronchiectasis is present in the collapsed lobe. One of the first communications in this connection came from France, viz. by RIST, JACOB and TROCHÉ in 1917 Its title was "Pleurésie médiastinale et bronchiectasie" (Mediastinal pleurisy and bronchiectasis). As the title would indicate, it is evident that the existence of mediastinal pleurisy in the cases where this triangle was found was not doubted Ten years later RIST, JACOB, and SOULAS returned to this subject, and the title then employed showed that their conception had undergone a considerable change, for then it was "Deux nouveaux cas de bronchiectasie simulant de pleurésie mediastinale" (Two new cases

of bronchiectasis simulating mediastinal pleurisy). This clearly shows that the conception of mediastinal pleurisy was no longer accepted, but that bronchiectasis simulated a syndrome similar to it. SERGENT, BORDET, TOPSIE and SOREL also gave early descriptions of this condition.

The bronchiectasis was still assumed to be primary A flareup of an inflammation was believed to cause a change in the pleura Partly



Fig 106

due to induration of the latter, and partly due to chronic changes in the lung, a sclerosing inflammation was supposed to develop Later it became clear that the primary occurrence must have been a collapse of the lobe, with secondary bronchiectasis resulting

The interpretation of the triangular shadow as a collapsed lower lobe was also made by others, viz ELLIS, LEEMDA and CURRAN, FINDLAY, MORLOCK and PINCHIN, SPARKS and MOLL The first case to be correctly interpreted in our clinic occurred in 1932

A 23 years old man had taken the rest cure 3 years previously,

because of a leftsided pleurisy. After six months he had resumed his work but continued to expectorate sputum. Three months later his complaints increased following a cold He was referred to the clinic because of his troublesome productive cough Prior to this, an experienced phthisiologist had reported a triangular shadow in the left lower part, and, in view of the typical picture, considered that it was mediastinal pleurisy which had broken through into a bronchus. Paravertebrally in the left lower chest dullness and bronchial respiration were found In the X-ray a definite triangular shadow was visible within the cardiac shadow.

The right anterior oblique projection (fig 106), taken after the introduction of lipiodol, made it clear that the triangular shadow was that of the considerably reduced left lower lobe. The left lower bronchus (*e*) exclusively supplied this very small part of the lung, in which bronchiectasis was present The air-containing part was supplied only by side-branches of the upper bronchus (*d*), and showed compensatory emphysema The apical bronchus was not filled. The filling was performed by means of a catheter· (*a*) is the section of the trachea, (*b*) and (*c*) of the right and left main bronchi

From clinical experience with foreign bodies it has been observed that this picture of an extensively collapsed lobe with the paravertebral shadow may arise rapidly, even in the course of few days Time and again we have noted that in such a lobe bronchiectasis always results if the occlusion of the bronchus is not immediately removed

It is remarkable that in the literature the importance of accessory lobes continues to be discussed in relation to this triangle. No doubt they may occur once in a while, but one is almost always dealing with a markedly reduced lower lobe, or possibly even lower and middle lobes. Pictures are found in the literature in which similar triangular shadows were interpreted as a cardiac lobe in which bronchiectasis had developed In our clinic the examination of many hundreds of lungs failed to disclose one cardiac lobe It may exist, but it certainly is extremely rare.

The occurrence of a triangle in the roentgenogram is largely the result of certain anatomical relations. The angle at which the border between the diseased and the healthy parts is struck by the roentgen-rays is also important. A lobe may be considerably reduced without a triangle being visible in the X-ray. In the discussion dealing with the stop, a few cases have already been referred to in which an obvious triangle was present in the picture. In the following case special

attention will be paid to the greatly altered topography of the bronchial tree

A 10 years old boy was admitted to the pediatric clinic with a bad family history of tuberculosis Of 13 children 6 had died of tuberculosis, and 3 others were in a sanatorium The child had become ill 8 months previously with cough and sputum, and on three occasions the sputum was blood stained For a long time the temperature

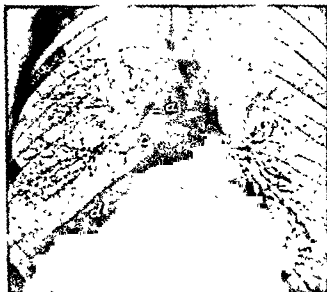


Fig 107

fluctuated between 101° and 102° F, but during the last 6 weeks it had been normal Von Pirquet's skin test was positive In the right lower area marked dullness was found, and the respiratory sounds were diminished In the roentgenogram a shadow was visible beside the right hilus, probably due to tuberculous hilar glands Still more important was the abnormality in the lower part, where a typical CHAUFFARD's triangle could be seen

The bronchogram (fig 107) immediately indicates the interpretation of the shadow (d) It is an atelectasis of the right lower lobe, apparently caused by an occlusion of the lower lobe bronchus The stop is visible

at *a*. From a closer study of the bronchial tree, it appears that the air-containing part on the right is exclusively supplied by the upper (*b*) and middle (*c*) lobe bronchi. A very rare anatomical variation is present. The upper lobe bronchus branches off at the lowest point, nearly at the same level as does the middle lobe bronchus, and, in consequence, the right main bronchus is of an exceptional length



Fig 108

Bronchoscopy disclosed that the right lower lobe bronchus was occluded by readily bleeding granulations These were removed as far as possible, and microscopic examination showed tuberculosis. Apparently, a tuberculous gland had broken through into the bronchus. In these cases, generally, the typical point of rupture is the lateral wall of the right main bronchus. Bronchoscopy may sometimes be life-saving by removal of caseous masses and granulations, as was also observed in a number of our children patients.

The triangular shadow in the right lower half persisted, but became smaller and smaller in the course of the following years, and apparently considerable shrinkage had taken place in the lower lobe. Six years later bronchography was again carried out In the bronchogram (fig 108) it is seen that the right lower lobe bronchus (*a*) has reopenend, but a marked stenosis is visible The lower lobe has certainly reached



Fig 109

its minimum size, and is reduced to a small paravertebral area. Obvious bronchiectasis is present

As in fig. 107, the air containing part is supplied by the upper and middle lobe bronchi only. In this bronchogram, too, our attention is immediately drawn to the anatomical variation Compensatory emphysema has developed, especially in the middle lobe which is much larger than normal The marked changes in the topography are particularly obvious in the lateral bronchogram (fig 109) In normal circumstances the middle lobe occupies a wedge-shaped space

in the anterior part of the chest, its base in front extending from the 4th to the 6th rib. Here, this lobe occupies a much larger area. Normally the two side-branches (4 and 5) run forwards, (4) more laterally and (5) more medially, the lateral branch in fig 109, however, has a markedly backward course. The bronchiectasis in the considerably retracted lower lobe is clearly seen. The middle lobe now supplies



Fig 110

the air containing area in the lower posterior half of the chest, and the deep niche between the diaphragm and the dorsal wall of the thorax has been occupied by it This was an example of a maximum displacement of the middle lobe towards the base and the back In the following case, however, a maximum upward displacement is present

A 38 years old man had been treated for pulmonary tuberculosis for 7 years Bilateral shadows were visible in the upper fields of the lungs Apparently, it was a process with cicatricial retraction, the shadows grew gradually smaller and became more displaced towards

in the series of X-rays. The patient was sent to the clinic because his sputum was persistently positive. The bronchogram (fig 110) is certainly interesting. Obviously, an extensive retraction has taken place in the upper lobes. The right upper bronchus is completely occluded and not filled at all. The stop is indicated by an arrow. In the left upper lobe, too, marked retraction has occurred, the involved part of the lung occupying only a small area in the upper field. On account of this, compensatory emphysema of the lower and middle lobes on the right side, and of the lower lobe on the left, has developed. Striking displacements have resulted. The basal bronchi of the lower lobe (8, 9 and 10) on both the right and left are pictured more apart than is seen in a normal dorso-ventral bronchogram. On the right this fanning out is particularly obvious if one considers the space between the cardiac (7) and the antero-basal (8) branches. Still more striking is the strongly ascending course of the middle lobe bronchus on the right and the lingular bronchus on the left. This is about opposite to what was seen in the picture of the preceding patient. The effect of bilateral influences in this case is very remarkable, and there must have been an almost radial traction on the tracheal wall. When there is a unilateral retraction the trachea is usually drawn sidewards, radial traction, however, will result in dilatation as can be seen in fig 110. Bronchiectasis may be caused in the same way.

b Displacements due to pressure. The displacements of the bronchial tree in the large group of patients discussed in the preceding pages, were due to collapse of certain parts of the lung. The space thus available was to a great extent occupied by expansion of the remaining parts. The group to be discussed now is also very large, and is related to quite different mechanical circumstances. In these cases the bronchial tree is passively pushed aside by a process filling a large space in the thorax. It may be situated within the lung itself, e g in cases of a large bronchial carcinoma it can often be seen that some bronchi have been displaced.

Some extra-pulmonary processes may take up a large space in the chest, thus causing considerable displacement, e g mediastinal tumours, pleural exudate and indurated pleura. The mediastinal tumour has usually attained great dimensions at the time the patient comes for treatment. The typical sign then found on bronchography is the displacement of the otherwise normal bronchi. Such a condition is illustrated by the following case.

A woman, aged 38, who had always enjoyed good health and had taken

part in sports, had developed a pain in the right chest six weeks previously. She had had a cough of some weeks duration, and complained of difficulty and pain on swallowing solid food. On examination there was dullness in the region of the sternum, and a very large shadow was seen in the X-ray. There was some divergence of opinion



Fig 111

as to this condition being a pulmonary or a mediastinal tumour, and she was sent to our clinic for more detailed examination

In the dorso-ventral bronchogram (fig. 111) it would appear to be almost certain that a mediastinal tumour is present. The two main bronchi have been pushed far apart, especially the right main bronchus being displaced sidewards and upwards. The bronchi are all well filled, and no stop is visible The whole group of bronchi of the right lower lobe has been pushed sidewards. At the level of the bifurcation

some lipiodol is present in the esophagus (indicated by *a*) Apparently, the esophagus is compressed at this point, and this may explain the difficulty in swallowing The patient was sent for surgery, and a neuroma, almost the size of a child's head, was removed from the mediastinum.

Another point of importance is that bronchography may provide valuable information about the location of the extra-pulmonary lesion A woman, aged 29, had had vague symptoms for 5 years, and complained of slight pain in the right shoulder and back She had two short periods of fever On fluoroscopy, a few months later, a shadow was seen on the right side of the heart At first a lymphogranuloma was suspected. The shadow gradually became larger, and after two years a circumscribed denser spot could be seen within the original shadow Gradually it became apparent that this was a tooth, and the diagnosis was established as a teratoma Bronchography was performed on this patient, 10 cc of lipiodol being introduced on the right side only In the dorso-ventral bronchogram it was seen that the bronchi of the middle lobe had been displaced slightly laterally This is particularly clear in the lateral bronchogram (fig 112) The dense round shadow in front reaches as far as the anterior wall of the thorax, and immediately attracts attention The bronchial tree is normal, except for the bronchi of the middle lobe All the large bronchi are present and there is no stop It is apparent that the two branches of the middle lobe have been pushed aside, as they spread round the dense shadow The tumour was, therefore, located medially of the middle lobe It was succesfully removed

Pleural conditions are frequently encountered, and they may cause considerable displacement of the bronchial tree The interpretation of the bronchograms of such cases is sometimes very difficult

A man, aged 51, had had a troublesome cough for four years, and expectorated as much as a few hundreds cc of fetid sputum a day The diagnosis was bronchiectasis of the left lower lobe, and he was sent for lobectomy Thirty five years previously he had had pneumonia on the right side, with empyema for which costal resection had been done In the lower area of the right chest, posteriorly, there was massive dullness, and diminished vesicular breathing with moist rales being audible Fluoroscopy revealed the presence of a dense shadow

Bronchography was performed In the dorso-ventral bronchogram (fig 113) the right upper lobe bronchus and its classical trifurcation are clearly seen The stem bronchus apparently bifurcates

into two branches, which can easily be mistaken for the bronchi of the middle and lower lobes An experienced observer, however, will soon recognize that (5) cannot possibly be the lower lobe bronchus, as in that case the segmental bronchi would be completely missing



Fig 112

The lateral bronchogram (fig, 114) reveals that (4) and (5) are the normal side-branches of the middle lobe bronchus In the dorso-ventral projection no branches of the lower lobe can be seen The lower lobe bronchus is situated behind the bronchi of the middle lobe, and divides into a few short *branches which appear to be almost rudimentary*. No bronchi are pr[illegible] large dorsally situated shadow.

When br[illegible] erformed [illegible] quantity of pus was seen co[illegible] and especially from its

postero-basal branch After the secretion had been removed by suction, lipiodol was introduced once more, but the same picture as that seen in fig 114 was obtained The right lower lobe, therefore, was abnormally small, and bronchiectasis could not be demonstrated On this account an extra-pulmonary condition was suspected, associated with the rupture into the bronchus of the accumulated pleural pus During



Fig 115

the operation a residual cavity with a bronchial fistula was found, being a sequel, therefore, to the empyema of 35 years previously

Patients suffering from affections of the pleura often develop extensive lesions which considerably reduce the space available for the lung Bronchography has made it possible to determine the effect of this on the lung, and also to estimate the degree to which it is affected *as a whole or in part This has long been a point of controversy* Also the problem of whether there is equal or unequal pulmonary ventilation, is of importance in pulmonary physiology and

pathology, e g. in the location of certain *conditions* like emphysema This should also be borne in mind when considering surgical collapse therapy. Should a local or a general effect on the lung be expected from the latter? From the many cases in which bronchography has been performed, it has become definitely clear that this effect is chiefly local. The pulmonary tissue close to the compressing lesion is col-



Fig 114

lapsed, but little or no effect can be observed in tissues situated further away The other lobes do not decrease in size.

A man, aged 58, had had a pleurisy on the left side at an early age. It resolved with considerable calcification. In fig 115 the pleural thickening on the left side and the extensive calcification can be clearly seen. Three months ago he became acutely ill, and had a temperature and much sputum. During bronchoscopy a great quantity of pus was seen coming from the left postero-basal bronchus (10) On bronchography it would appear that this bronchus shows slight

cylindrical bronchiectasis, in contrast to the latero-basal branch (9) where alveolar markings are seen

It is striking that the pleural thickening, involving chiefly the lower



Fig 115

part, gave rise to such a remarkable compression of the lower lobe The bronchi of this lobe are crowded together The upper lobe, on the other hand, is almost normally expanded

There is another unusual anomaly to be seen in this picture Attached to the medial wall of the main bronchus are many fringe like little

projections. During bronchoscopy several small apertures were seen opening into these projections which were lined with normal mucous membrane The picture is very characteristic. Small herniae of the mucous membrane might be thought of as an explanation, but they probably are retention cysts of the mucous glands which have broken through into the lumen They have also been described by POLICARD. Similar pictures were seen in patients with a chronic cough

Foreign bodies.

Bronchography is seldom performed in cases with a foreign body in the bronchi, because generally it is not necessary. Experience has shown that nearly all foreign bodies can be located by the signs of bronchostenosis, obstructive emphysema, and atelectasis, with which we have become familiar chiefly through the school of CHEVALIER JACKSON On the other hand, in particularly difficult cases bronchography can sometimes be helpful If, as is usually the case, the foreign body itself gives no shadow on the X-ray, important information may be obtained by using a contrast medium, e.g

1 whether a foreign body is actually present or not.

2 the exact location.

3 whether any particular complication is present or not

(1) Sometimes the history is very vague indeed, and examination of the chest may not reveal any abnormality. Bronchography and bronchoscopy should always be performed in these doubtful cases

A man, aged 57, had choked for a moment when taking soup a fortnight previously. Since then he had had a cough, and the possibility of his having aspirated a bone was considered Neither the routine nor the X-ray examination of the chest revealed any abnormalities. Bronchography was performed. A very suspicious looking shadow could be seen in the left main bronchus, especially in the residual bronchogram As has already been mentioned, these X-rays are often equivalent to a relief-picture, and a foreign body giving no shadow itself may thus be made visible because the lipiodol clings to it, showing the contours in the film A bone was in fact removed from the left main bronchus when bronchoscopy was performed It was similar in shape to the shadow in the bronchogram, and it was a chicken's vertebra

During the discussion on bronchostenosis, attention was drawn to the fact that in the few cases where bronchography was performed when a foreign body was present, a picture was usually seen very

much resembling those of an affection of the bronchial wall, e.g. a tumour or tuberculous granulations

A man, aged 34, developed a productive cough 3 years previously. Elsewhere, a shadow was found in the right lower part, which was considered to be a pulmonary infiltration VON PIRQUET's test was strongly positive The patient developed an abscess in the armpit, in which tubercle bacilli were found on one occasion The sputum was always negative A year ago the patient began to have haemoptyses which recurred repeatedly and became so serious that sometimes amounts up to 500 cc of blood were expectorated In spite of blood transfusions the haemoglobin percentage fell to 31% He was then sent to our clinic by the internist

His general condition was bad, and there was a continuous expectoration of blood In the right lower half of the chest there was dullness and diminished vesicular breathing Consideration was given to the introduction of a tampon into the right bronchus, but it was decided first to try an artificial pneumothorax The lung collapsed satisfactorily, and the haemorrhage stopped Fig 116 was taken after the introduction of lipiodol and the complete collapse of the lung is clear (A) is the bronchus of the upper lobe, (B) and (C) of the middle and lower lobes Bronchiectasis is present in the latter two There was an irregular clearance in the stem bronchus, indicated by the arrow It was suggestive of a tumour, but in view of the history tuberculous granulations had to be seriously considered When the patient's general condition had improved sufficiently, bronchoscopy was performed There were granulations in the stem bronchus, but these bled so profusely when removed, that the bronchoscopy had to be interrupted It was repeated 5 days later On this occasion a big bone was found covered by granulations, and it was removed Only then did the patient recall having aspirated it 3 years previously. This confirms the teaching of CHEVALIER JACKSON, that in cases of an obscure pulmonary disease the possibility of a foreign body should always be borne in mind

Fig 116 is also noteworthy from another point of view It shows how the anatomy changes, the bronchus of the upper lobe having descended considerably During bronchoscopy it was easy to enter this bronchus If in certain cases bronchoscopic intervention in the bronchus of the upper lobe is called for, a pneumothorax may be induced This expedient, first indicated by SOULAS, has already been employed in our clinic on a few occasions

(2) This is important when foreign bodies are present at the

periphery, as it furnishes important indications for bronchoscopy. As is known, foreign bodies of a vegetable nature are usually located in the main bronchi in the great majority of instances. Occasionally, especially if the foreign body was aspirated a long time previously, it disintegrates when extracted. While the smaller parts are generally coughed up through the tube, sometimes a piece finds its way into



Fig 116

the deeper air passages In such a case *bronchography may supply* information about its location in a peripheral bronchus. The following is an illustration. *A girl, aged 3, had aspirated a peanut a few hours* previously She was admitted to the clinic with obvious signs of a *check-valve occlusion of the right main bronchus and* obstructive emphysema of the right lung. By means of bronchoscopy half a peanut was removed *from the right bronchus. A small piece, however,* was missing, and during the bronchoscopy we got the impression that *it had disappeared into the periphery.* Although the child afterwards

showed no symptoms at all, bronchography was performed a few days later as a precautionery measure. In all bronchograms it was obvious that the piece had disappeared into the postero-basal lower lobe branch. Fig 117 is the dorso-ventral bronchogram In the postero-basal bronchus two accumulations of lipiodol are present, and between these a clearance is seen (see arrow), apparantly indicating the foreign



Fig 117

body In the lateral bronchogram a column of lipiodol was visible in the same bronchus at the same place On bronchoscopy the piece of peanut was found at that site, and it was removed

This procedure is important, because occlusion of a segmental bronchus may occur without producing any signs The collateral ventilation may prevent development of atelectasis under certain circumstances, as in the above mentioned case

(3) Another complication may be that a sharp object has pierced

the bronchial wall. If no acute symptoms are present, this condition can only be demonstrated with certainty by bronchography.

A man, aged 25, had aspirated a paper-fastener six years previously. After a year he expectorated blood, but the paper-fastener incident was then forgotten The haemoptyses recurred, he developed pneumonia and began to expectorate large quantities of fetid sputum. A few weeks ago, the internist found a lesion in the lower part of the right lung, and on X-ray examination he established the presence



Fig 118

of a foreign body Only then did the patient recall the paper-fastener incident, and he was sent to our clinic for treatment. In the X-ray a shadow could be seen on the right side of the heart. The paper-fastener was visible, its legs being far apart and pointing upwards Orthodiagraphically it could be ascertained that the ends were 15–16 mm apart, which is a large dimension for a foreign body situated so deep in the air passage There was every reason, therefore, to assume that one of the legs had pierced the bronchial wall The situation became quite clear on examining the bronchogram (fig 118). The bronchus of the upper lobe was not filled, but the branches of the middle lobe bronchus were clearly seen. The medially situated

leg of the paper-fastener protruded half an inch through the bronchial wall Its head was near the upper part of the lower lobe bronchus, and there was an accumulation of lipiodol on top of it It was decided that at bronchoscopy an attempt would be made to follow the method of CHEVALIER JACKSON, and first push the paper-fastener down, so that the medially situated leg would come out of the wall, and then try to close the paperclip, or if possible to pull it legs downward into the tube The bronchoscopy was impeded by the presence of great



Fig 119

quantities of fetid pus and granulations which bled readily Eventually, the paper-fastener was seen in the bronchoscope, and it was carefully pushed down Suddenly it disappeared Once more bronchography was performed (fig 119) The bronchi of the upper, middle, and lower lobes were well filled The paper-fastener had fallen down, and it was now situated in the postero-basal segment, at the outer periphery of the lung, and in one of the large bronchiectatic cavities of the collapsed lower lobe As the patient expectorated great quantities of fetid pus, it was decided to remove the bronchiectatic lower lobe, including the foreign body The lobectomy was performed with complete succes

Special applications of contrast oil.

By means of contrast oil it is possible to fill both normal and abnormal cavities and passages, thus making them visible in the roentgenogram In oto-rhino-laryngology we often use *lipiodol for* outlining the nasal accessory sinuses and cervical fistulae. In the deeper air passage, too, various applications are possible, and a few of the most important will now be described.

Bronchography is chiefly concerned with the bronchi, but important information may also be obtained about the trachea and the larynx The normal anatomy can be studied. In the bronchogram the protuberance of the aorta into the left lower half of the trachea is often very well marked. Similarly anomalies may be seen, e.g aneurysm, tumours in the trachea, and displacements due to the presence of an extrinsic tumour or the pressure of an enlarged *hilar* gland. We found that the application of lipiodol in cases of children with laryngeal stenosis was particularly helpful These often require prolonged *treatment by dilatation By introducing a small quantity of lipiodol* into the tracheostoma, the head hanging down, an excellent picture of the stenosis is obtained, and comparison with preceding X-rays will show *the degree of improvement*

Asthma occasionally gives characteristic pictures Stops are often present due to secretion, the peripheral bronchi being narrow (increased tone of the bronchial muscles). In some cases it has been possible to demonstrate in the bronchogram the widening of the bronchi produced by antispasmodics

In pleural affections, sometimes a better insight may be provided by the introduction of contrast oil into fistulae, and, particularly, into residual cavities We succeeded on a few occasions in demonstrating with certainty a bronchopleural fistula, by introducing lipiodol into the pleural cavity *After a few minutes it was visible* in the air passage SERGENT and COTTENOT first succeeded in demonstrating the fistula itself

Pitfalls in bronchography

Pitfalls in bronchography *are numerous*, and it is not always easy to interpret a bronchogram correctly. In some cases this can only bedone after a very accurate study of a whole series of X-rays. In a way, they *somewhat* resemble the difficulties of a chess problem. A case of this type will be discussed later on.

Difficulties in interpretation are, as a rule, encountered in cases where only a single picture has been taken Reference to the literature shows that this frequently leads to serious mistakes Lipiodol in the esophagus might be mistaken for a cavity in the lung or bronchiectasis The same may happen if the lipiodol remains level in a horizontal bronchus Pictures taken in another direction will usually help the right interpretation



Fig 120

Insufficient or excessive fillings of certain parts of the lung, in particular, may produce pictures which give rise to mistakes In the former case an occlusion of the supplying bronchus may be suspected, while in the latter circumscribed shadows may be seen in the bronchogram, "les lacs d'opacification", due to excessive filling of the alveoli. These shadows are sometimes mistaken for cavities in the lung or bronchiectasis Insufficient or excessive fillings of certain areas are usually due to technical faults. However, such happenings will occur

in a certain percentage of cases Confusing pictures often are the result, as shown by the folllowing example

A man, aged 69, had developed pneumonia in the lower part of the right lung six months ago. He continued to cough and to expectorate Marked dullness and diminished respiratory sounds persisted in the right lower area, and in the X-rays a shadow was visible. Staphylococci were found in the sputum, and penicilline brought about a marked improvement Later on his complaints again became worse, and, as the shadow persisted, the possibility of a tumour, an abscess, or bronchiectasis was considered. Tomography showed a definite shadow in the posterior region, but no cavities were found

Fig 120 is the dorso-ventral bronchogram, after the introduction of 10 cc of lipiodol into the right lung. C is the upper lobe bronchus The anterior branch is well filled, the posterior branch being only partly outlined The apical branch is not filled at all The right upper lobe occupies a relatively larger area than normal, the anterior branch extending far downwards.

Further on, the stem bronchus appears to bifurcate into 2 branches A and B A cursory examination would give the impression that B is the middle lobe bronchus and A the lower lobe bronchus In that case, however, the space occupied by the latter lobe would be extremely small Apart from these important topographical changes, no anomalies are seen The bronchi A and B supply normal parts of the lung, and a fine alveolar structure is shown by the lipiodol Many alveoli are filled with lipiodol, particularly in the part of the lung supplied by A A pronounced shadow is seen here, but in this projection it is obvious that this is not due to single a cavity, but to a great number of smaller ones

Fig 121 is the lateral bronchogram, the branches A and B can be easily found again In that part of the lung supplied by A, a more marked shadow is now seen, and it is an example of a "lac d'opacification" In the lower half the shadow is so marked in this projection, that a cavity might be suspected. Higher up, however, a more tenuous alveolar structure can be seen, and we can compare it with fig 120 This structure, always present somewhere at the margin, makes it easy to recognize these "lacs d'opacification"

At once it would appear doubtful if A is actually the lower lobe bronchus, and it would then seem more probable that A and B are both side-branches of the middle lobe bronchus. If this should be the case, it would be situated in an abnormal position, much more inferiorly and posteriorly than in normal. The middle lobe also lies

on the posterior part of the diaphragm, close to the front of the spine

One might suppose that behind A there is some process, such as a tumour, which has pushed the lower lobe bronchus A considerably forwards. The lumen of A and B are very small when compared with the lumen of the trachea It appears, however, that only the ventral



Fig 121

walls of the trachea, main bronchus, and stem bronchus are marked by the lipiodol There is very little lipiodol on the dorsal wall, and only the ventral bronchi are filled

Fig 122 is the lateral bronchogram, after the introduction of 10 cc of more lipiodol into the right lung, while the patient was held in a reclined position The dorsal bronchi are now well filled, and the topography is clear A and B are both side-branches of the middle lobe bronchus, and their common origin from the stem bronchus is clearly seen

At point C the upper lobe bronchus branches off from the main bronchus, D is the lower lobe bronchus. The area supplied by the latter is extremely small, and it only occupies a narrow strip in front of the spine Except at E, a fine alveolar structure is present everywhere, and no cavities or bronchiectasis are seen in the lower lobe. The



Fig 122

terminal bronchus at E has a pathological appearance. Normally, however, the lower lobe extends much further down and backwards over the spine The next bronchogram makes it clear that this remarkable picture has arisen from the fact that these bronchi are

postero-basal part. On account of this the larger bronchi ... periphery, simulating bronchiectasis.

Fig 123 is the residual bronchogram, also taken laterally. The pul-

monary tissue near E has now been filled with lipiodol, and also shows fine alveolar markings So there is certainly no bronchiectasis present.

The posterior margin of the pulmonary tissue is indicated by the arrows This margin lies much more to the front than normally, the lower part being even in front of the spine The lower lobe which



Fig 123

is very much reduced in size and displaced backwards, is also encroached upon from behind by a process situated behind both the lower part of the upper lobe and the lower lobe This can only be a lesion of the pleura tumour or inflammation A puncture by means of a trocar, as used for liver biopsies, was done to procure a specimen of tissue for further examination It proved to be connective tissue with residues of inflammation The shadow in the right lower area was, therefore, caused by induration of the pleura The latter was thus responsible for the forward displacement of the lower lobe.

The striking change of position of the lower lobe bronchi, also posteriorly, is remarkable. The middle lobe now is occupying the space previously filled by the lower lobe. It must almost be assumed that an inflammatory process in the latter lobe, i.e. a pneumonia followed by pleurisy has led to the formation of a thick induration and a collapse of the lobe. This was probably due to a temporary



Fig. 124

occlusion of the lower lobe bronchus, as is often seen in inflammatory processes. In such cases the actual relationship can only be made clear by means of bronchography. Tomography alone, cannot indicate the considerable topographical changes which are of the utmost importance for the correct interpretation of the process.

Aside from the significance of insufficient filling, certain anatomical conditions may also be of importance. REICHLE demonstrated on test animals that a fluid injected into a lung always reached the same parts,

because it followed the course of certain folds of the mucous membrane. These longitudinal folds are sometimes very striking when seen in the opened preparation of a lung Possibly they are responsible for the picture in fig 124 It is the dorso-ventral bronchogram of the right upper lobe of a 29 years old woman She had had a productive cough for many years Bronchiectasis was suspected, but it was not found



Fig 125

on bronchography A cursory examination of fig 124 may give the impression that a stenosis of the right upper lobe bronchus is present It is noteworthy, however, that while the anterior and posterior branches are fairly well filled with lipiodol, the upper and lower walls of the upper lobe bronchus are poorly outlined Furthermore, it appears as if the apical bronchus were completely absent, although higher up in this area filling of some bronchi is present This indicates insufficient filling and, therefore, more lipiodol was introduced,

the patient adopting a markedly sidewards position. Fig. 125 is the result. There is no question of a narrow bronchus, and while the lower margin of the right upper lobe bronchus has remained unaltered, the upper wall is now clearly visible It is likely that the regular contour in fig 124, simulating the upper wall, was only a fold in the mucous membrane The unsatisfactory filling probably resulted from the presence of secretion, which is so often deceiving in bronchography. In strong support of this is the fact that a great quantity of lipiodol has run along the right wall of the trachea higher up Later it deviated from the trachea, and formed a small accumulation in the lumen So, probably, something was present on the right wall of the trachea, interfering with the further course of the lipiodol In fig. 120 we saw that when a filling is insufficient, due to an incorrect position, the lipiodol can be observed higher up in the air-passage, but not outlining the wall concerned This is another example of the need for accuracy in the study of a bronchogram

Excessive fillings are often due to introducing a catheter too deeply. In such a case, all the lipiodol may be injected into one or only certain lung segments Near the pleura these accumulations of lipiodol generally display a sharp margin If the catheter is introduced still further into a side-branch, the corresponding segment may be extensively filled with lipiodol, and one might call this a lipiodol infarct It can be clearly demonstrated by the anatomical injection of the lungs in cadavers

The essential point in the formation of the "lac d'opacification" is the entrance of lipiodol into the alveoli. We have already stated in a previous chapter that in some degree ("arbre au printemps") this is important for diagnostic purposes, to a greater extent, however, it is rather a disadvantage If many alveoli are filled we can no longer study the bronchi, and a deceptive picture will result. The extent to which lipiodol enters the alveoli varies very much in different cases It is chiefly seen in patients with emphysema The phenomenon has not yet been sufficiently studied, but it depends largely on factors such as cough and the temperature of the lipiodol It is certain, however, that anatomical conditions at the periphery play an important part. This view is supported by the fact that the filling of the alveoli is different in the lungs of various mammals.

CHAPTER VII

THE TECHNIQUE OF BRONCHOGRAPHY IN THE GRONINGEN UNIVERSITY CLINIC

The standard technique

The diagnostic results achieved by contrast examination of the bronchial tree, depend largely upon the technique employed in the procedure. The complicated structure of the bronchial tree makes particular demands on the technique of bronchography, and it is of great importance to make this examination in accordance with a standardized method. This applies both to the manner in which the lipiodol is introduced, and the way the roentgenograms are made.

Over a period of many years, a standardized method for bronchography has been developed in the Groningen clinic, and it has proven very satisfactory. Almost all patients — unless a contraindication is present — are bilaterally examined at one sitting. A complicated technical apparatus is quite unnecessary for bronchography. In fact, excellent results can be achieved, employing very simple equipment. In this chapter a detailed description is given of our standard technique for bronchography. All bronchographies are performed in the Radiological department of the University Clinic, in cooperation with the radiologist.

Instrumentarium. The instrumentarium used for the lipiodol examination, always consists of the following items for each adult patient (fig. 126a):

2 ampules of lipiodol Lafay each containing 10 cc
1 bottle of a sterile 1% solution of pantocain
1 bottle of sterile 0.1% solution of suprarenin
some sterile strips of gauze
1 porcelain cup of about 25 cc capacity
1 plate
1 *small kidney dish*
1 atomizer, model de Vilbiss, with adjustable nozzle
1 tongue depressor
1 laryngeal mirror of the usual type.

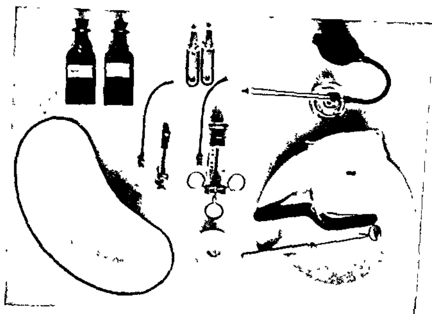


Fig 126a The instrumentarium for adult patients

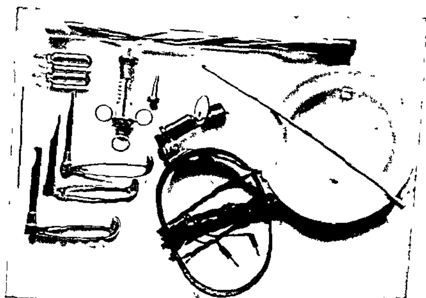


Fig 126b The instrumentarium for children.

Fig 126 The instrumentarium for bilateral bronchography

1 Record syringe of 2 cc, to which a thin laryngeal cannula can be fastened by means of a bayonet catch.

1 Record syringe of 20 cc, to which in the same way a laryngeal cannula of a large diameter can be fixed.

For the lipiodol examination of young children the instrumentarium is less extensive, and consists of the following items (fig. 126*b*).

2 ampules of lipiodol LAFAY, each of 10 cc

1 plate

2 laryngeal spatulae of different sizes, according to KILLIAN.

1 glass tube containing a few sterile semi rigid catheters of calibre Ch 14—16

1 Record syringe of 20 cc, with a lengthening-piece on which the catheters can be fitted

1 electric forehead lamp.

The instrumentarium is carefully sterilized before each bronchography

Preparation of the patient. Every lipiodol investigation should be preceded by a careful preparation of the patient. The bronchographic examination is never performed on outpatients As far as patients who are hospitalized in one of the other departments of the University Clinic are concerned, the preparation is done there Patients from elsewhere are admitted and prepared in our department All data concerning the patient must be studied beforehand They frequently give important information about the nature and the localization of a pathological process This is of significance in determining the side into which the lipiodol should first be introduced

During the preparation the first point to be decided is whether any of the contra-indications discussed in chapter III are present or not Secondly, the patient is examined for idiosyncrasy for iodine and pantocain. For iodine this is tested by means of a small internal dose of potassium iodine, and also by means of the cutaneous reaction to tincture of iodine Idiosyncrasy for pantocain is determined by means of the cutaneous reaction to a 2% solution In a certain percentage of cases an idiosyncrasy, usually slight, for iodine exists An idiosyncrasy for pantocain is only rarely found. Idiosyncratic patients are treated with antallergan (a drug of the anti-histamin group) for a few days, and are thus temporarily desensitized If the tests for idiosyncrasy are (for the time being) negative, the lipiodol investigation can be performed without any objection

The bronchographic examination should be done on an empty

stomach. Thus the risk of aspirating regurgitated food is avoided Obviously, complete or partial dentures must be removed from the mouth beforehand

Patients who are considered on clinical grounds to be suffering from purulent bronchiectasis, and, generally, patients expectorating considerable quantities of sputum, are drained a short time before the investigation This is done by means of postural drainage for at least half an hour To obtain satisfactory bronchograms of such patients, it is of the greatest importance that the secretion should be previously removed. A large quantity of secretion is very troublesome, because it prevents adequate anaesthesia of the bronchial wall and, in addition, it considerably hampers the spreading of the lipiodol into the bronchi

Before the examination, a simple explanation of the method to be followed is given to the patients The importance of the investigation to be performed is pointed out, and an appeal is made for their cooperation They are asked to breathe quietly and regularly during the introduction of the lipiodol, and not to cough or swallow We have repeatedly found that this simple instruction contributes considerably to the calm and undisturbed performance of the procedure

Prior to the lipiodol investigation, the patients are not, as a rule, treated with sedatives, only very nervous persons being sometimes given a sedative beforehand In cases with a bad cough 15 mg (¼ grain) of codein or 20 mg (⅓ grain) of pantopon is administered. All patients receive 100 mg (1½ grains) of phenobarbital one to two hours before the bronchography.

Anaesthesia. Almost all bronchograms are made with the assistance of a preliminary slight surface anaesthesia of the mucous membrane of the base of the tongue, the pharynx, the larynx, the trachea and the large bronchi For the surface anaesthesia of the base of the tongue and the pharynx a one percent solution of pantocain is used. For the anaesthesia of the larynx, the trachea and the large bronchi a small quantity of adrenalin is added This is done to diminish a possibly existing swelling of the bronchial mucous membrane It may be of importance, for example, in enabling lipiodol to enter a bronchus which would otherwise be occluded by a swelling of the inflamed mucosa At the same time the adrenalin prevents a too rapid absorption of the pantocain present in the bronchi. In cases of hypertensive and cardiac patients the addition of adrenalin is omitted — usually after

consultation with the internist — to prevent undesirable additional effects, as adrenalin is quickly absorbed by the bronchial mucous membrane. As early as 40 seconds after its introduction into the trachea a raised adrenalin percentage in the blood can be demonstrated. For the same reason, we also omit the addition of adrenalin in patients beyond the age of 60 years. To 5 cc of one percent pantocain solution a few drops of adrenalin solution 1 in 1000 are added.

A satisfactory anaesthesia of the mucous membrane of the base of the tongue, the pharynx and the vestibule of the larynx is obtained by twice spraying the soft palate, the palatal arches, the posterior wall of the pharynx, the base of the tongue and the larynx with the one percent pantocain solution. After a few minutes a little of the pantocain-adrenalin solution is dripped into the larynx by means of a laryngeal syringe. This is checked with a laryngeal mirror, the patient himself firmly pulling out his tongue with a strip of gauze, in a sitting position. It is advisable not to introduce the pantocain-adrenalin solution too rapidly, but drop by drop, and to make the patient emit a sound at the same time. In this way a very good anaesthesia of the vocal cords is obtained, and the anaesthetic descends slowly and gradually into the trachea and the bronchi. As a rule, the penetration of the liquid into the deeper air passages excites a strong cough reflex, but the latter usually disappears in a few seconds.

There are many reasons for performing the intratracheal introduction with the minimum amount of the pantocain-adrenalin solution. Some patients have a much stronger idiosyncrasy for pantocain than the previous cutaneous reaction would lead us to suspect. A few minutes after the intratracheal introduction of the solution a marked reaction may occur, sometimes even with a fatal after-effect. Our clinic has had some unfortunate experiences in this respect. One case observed by us was that of a woman about 60 years of age, whose general condition was poor. A few minutes after the intratracheal introduction of the pantocain-adrenalin solution, a total of 2 cc., a rapidly increasing unconsciousness developed, followed by irregular convulsions, a rapid irregular pulse, and a cessation of respiration. The patient died about five minutes later. Some time previously we observed another case, that of a man about 60 years of age, who also succumbed in the same rapid way and with similar phenomena. The autopsy disclosed a tumour with cerebral metastases. The very small dose of adrenalin administered to these patients did not fully account for the deaths, so the cause was sought in a strong idiosyncrasy for the pantocain-solution used. A mistake in the

preparation of the liquids in the dispensary could be ruled out. It is possible that in these cases, in view of the very poor general condition, the manipulations may have been chiefly responsible for the deaths, and perhaps the anaesthesia also contributed to it. These experiences have led us to exercise the utmost care with the intratracheal anaesthesia In our long series of bronchographies we have not encountered any further complications of importance. These two fatal cases were the only instances of this kind in a series of many thousands of bronchographies at our clinic

For reasons other than idiosyncrasy, the introduction of too large a quantity of pantocain-adrenalin solution is undesirable. It produces anaesthesia of the bronchial mucous membrane to an extent much greater than is necessary for the lipiodol examination, and lasting too long. In consequence, the patient does not expectorate the lipiodol to a satisfactory extent after the investigation. The absence of the cough reflex, particularly in patients with purulent processes, may result in infectious secretion reaching healthy bronchi. Thus, the added risk of secondary infection should not be forgotten. We have a strong impression that the — fortunately rare — rise in temperature following the examination is due to this.

Experience teaches that, as a rule, intratracheal anaesthesia of a slight degree is sufficient. Even very nervous and hypersensitive patients present no particular difficulties In the case of calm patients we have on many occasions succeeded in making excellent bronchograms without any previous intratracheal anaesthesia. In this group we contented ourselves with spraying the palatal arches, the posterior wall of the pharynx, and the vestibule of the larynx a few times with the one percent pantocain solution The lipiodol was warmed to body temperature and appeared, when slowly dropped into the trachea, to cause very little cough reflex Generally speaking, however, — and this particularly applies to those who have not had a wide experience in this matter — it is advisable to employ a light intratracheal anaesthesia. A total quantity of 1 to 2 cc of pantocain-adrenalin solution is usually fully adequate. Half this quantity is dropped in with the patient inclining slightly to the right This anaesthesizes the mucous membrane of the trachea and the right main bronchus. Subsequently the patient must incline fairly markedly to the left, so as to direct the remaining part of the anaesthetic along the left wall of the trachea into the left main bronchus. The cough reflex appearing in the first moments, further spreads the anaesthetic, so that after 2 to 3 minutes an adequate anaesthesia is achieved.

In the literature the use of cocain solutions of varying strengths is fairly generally recommended for the intratracheal anaesthesia In the Groningen clinic, however, the less toxic pantocain solution is used exclusively, so that we have no experience with the application of cocain solutions for these purposes

The introduction of the lipiodol into adults When introducing the lipiodol, one should aim at filling all bronchi as completely as possible, particularly in the upper lobe areas A very good technique of filling is necessary to permit the lipiodol to penetrate into this part of the bronchial tree Various opinions have been expressed in the literature, concerning the quantities of lipiodol which are necessary for a unilateral filling This quantity should be just sufficient to render all bronchi visible Generally speaking, excellent results can be obtained using 10 cc of lipiodol It is enough to fill the bronchial tree well, but not too abundantly, to its outermost ramifications At the same time we have found that sometimes 10 cc is not quite adequate to fill the area of the lower lobe bronchi satisfactorily following the filling of the upper lobe bronchi For this reason, in some cases we use about 12 cc of lipiodol for a unilateral filling This applies principally to the right side in which the total surface is slightly larger than on the left It is particularly desirable when the patient is tall and square built, and so may be assumed to have a large bronchial tree Also if clinical and other data make the existence of extensive cavities in the lung probable, it is advisable to use larger quantities of lipiodol, e g 15 to 20 cc for a unilateral contrast examination However, if particular indications are absent, a quantity of 10 cc is, as a rule, sufficient

At ordinary room temperature lipiodol is thickly fluid and not so well suited for intrabronchial use, it should, therefore, be warmed prior to the investigation The views concerning the most suitable temperature are rather divergent We prefer a temperature of about 75 to 85 degrees Fahrenheit When lipiodol of a higher temperature is used, a considerable alveolar filling is apt to occur, which largely detracts from the clarity of the bronchograms For the contrast examination of young children, to be described more fully later on, the lipiodol is always warmed to body temperature In children the procedure is usually performed without anaesthesia, and to prevent a strong cough reflex, lipiodol of a higher temperature than for adults is employed

To introduce lipiodol into the trachea a 20 cc syringe is used, fitted with a laryngeal cannula. We rarely feel the need of a catheter in introducing the contrast medium and, as a rule, we consider the transglottic catheter method — at least for adults — as unnecessarily complicated

The lipiodol, warmed to 75 to 85 degrees Fahrenheit, can be introduced just as well supraglottically, according to the technique of PRITCHARD and WHYTE (into the vestibule of the larynx), as transglottically. In practice this appears to make little difference. According to the method of SINGER, the lipiodol is simply squirted against the back wall of the pharynx or the palatal arches and, subsequently, automatically aspirated. Although this method of introduction is very simple, indeed, and offers great advantages, it proves to be less satisfactory. It is not infrequently observed that a fairly considerable quantity of lipiodol remains in the pyriform sinus, thus resulting in an insufficient amount of contrast oil reaching the bronchi Moreover, the possibility exists with this method, that infectious material present on the pharyngeal wall or the tonsils, may be introduced into the bronchi with the lipiodol.

To obtain a satisfactory filling of all branches of the bronchial tree it is necessary to direct the patient to assume different positions in a certain sequence, during and immediately following the introduction of the contrast oil These positions are closely bound up with the direction in space of the various segmental bronchi, and one should, therefore, be thoroughly acquanted with the anatomy.

On account of the somewhat special technique for the filling of the upper lobe, it is undesirable to inject the whole amount of lipiodol in one movement The upper lobe area is apt to take up more of it than is desirable for a good picture should the quantity of lipiodol in the upper bronchus be too large. Thus an excessive alveolar filling will result Considered by itself, this would not be such a disadvantage, but experience shows that the upper lobe bronchi sometimes take up the greatest part of the available lipiodol, thus making an adequate filling of the lower lobe branches completely impossible. During the filling of the apical and posterior upper lobe bronchi, the patient is placed in the Trendelenburg position for a time. The remaining lipiodol still present in the main bronchus, and intended for the filling of the lower lobe bronchi, will flow back into the trachea. It is sometimes even seen to drop out of the mouth To avoid this we prefer to ration the upper lobe when filling it, which makes it necessary to inject the lipiodol for the upper and lower lobes fractionally. In this way a satisfactory filling of all segmental upper lobe

branches is obtained, whereas an excessive filling of the alveoli cannot occur, due to the lack of lipiodol This also has the advantage that no considerable quantity of lipiodol remains in the main bronchus, and thus the return back flow when assuming the Trendelenburg position, is avoided



Fig 127 The position of the patient for the introduction of lipiodol into the right upper lobe bronchus and its segmental branches (1)

The introduction of lipiodol into the right bronchial tree will first be described The patient who is seated on a small bench without back or arms for this procedure, inclines markedly to the right side, so much so that he finishes by resting on the flat palm of his right hand on the floor His head is supported by a helper if necessary, and is held as erect as possible, the patient himself firmly pulling out his tongue with his mouth wide open, and at the same time breathing quietly and deeply Four cc of lipiodol are now in-

jected slowly (checked by the laryngeal mirror) by means of the *syringe fitted with the laryngeal cannula, of which the end is slightly* below the level of the glottis (fig. 127). The lipiodol flows along the right wall of the trachea into the right main bronchus, and thus into *the upper lobe bronchus. We wait for a few seconds to give all the* contrast oil the opportunity of reaching and entering this bronchus. Its anterior branch takes up sufficient lipiodol during this time. The patient now bends his right elbow, *a helper fixing the hips in order*

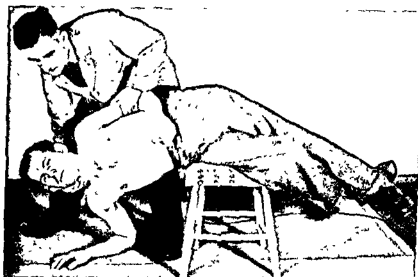


Fig 128 The position of the patient for the introduction of lipiodol into the right upper lobe bronchus and its segmental branches (II)

to prevent his sliding off the bench He assumes a marked sideward Trendelenburg position for 10 to 20 seconds, and the apical branches become filled (fig 128) Subsequently, this sideward Trendelenburg position is gradually changed into a dorsal posture, in which the posterior upper lobe bronchi are filled (fig. 129) It is of the utmost importance that the patient behaves passively during these somewhat unpleasant movements, and at the same time continues to breathe *quietly, regularly and deeply. After about ten seconds* it can be accepted that the posterior branches have taken up sufficient lipiodol The patient is then carefully brought back into a sitting position, and at the same time he has to incline slightly to the right and considerably forwards. During this change of posture care should be

taken that the right half of the thorax continually is the lowest part, so as to prevent the lipiodol, still present in the right main bronchus or flowing back into it, from reaching the left main bronchus

Subsequently, the middle and lower lobe bronchi are filled First of all the branches of the middle lobe, by injecting fairly rapidly 2 cc of lipiodol, the patient being seated in the position assumed after the filling of the upper lobe bronchi The contrast oil flows along the right side of the anterior wall of the trachea and the right main



Fig 129 The position of the patient for the introduction of lipiodol in the right upper lobe bronchus and its segmental branches (III)

bronchus into the middle lobe branches As a rule, it can be accepted that after about 10 seconds the middle lobe bronchi will be sufficiently filled in this way (fig 130) *For the lower lobe bronchi the posture* of the patient must be slightly changed and it must now be approximately upright, with the upper part of the body somewhat inclining to the right This inclination to the right should not be exaggerated, however, as otherwise an insufficient filling of the cardiac and posterobasal branches may result Subsequently, the last 4 cc of lipiodol are slowly injected (fig 131) All segmental branches of the lower lobe bronchus now get the opportunity of being filled, except the apical

To fill the latter bronchus the position of the patient during the injection of the last few cc is changed once again From his upright posture he is directed gradually to assume a more backward inclining position. Attention should be paid to it that he continues to *incline slightly to the right (figs. 132 and 133). The last* remnant of the lipiodol injected in this *position* will *flow* down *along the right side*



Fig 130 The position of the patient for the introduction of lipiodol into the right middle lobe bronchus and its segmental branches

of the posterior wall of the trachea and the right *main* bronchus Thus the apical branch of the lower lobe bronchus will be well filled, as also will be the other side-branches which come *off* from the basal segmental bronchi, taking a dorsal direction. The filling of all lower lobe bronchi requires about *20* seconds. *After this, the patient* is directed to assume a final sitting position, slightly inclining forwards and to the right (fig 134) So all told, the introduction of the complete lipiodol filling into the right bronchial tree takes a full minute.



Fig 131 The position of the patient for the introduction of lipiodol into the segmental branches of the right lower lobe bronchus (I)



Fig 132 The position of the patient for the introduction of lipiodol into the segmental branches of the right lower lobe bronchus (II)



Fig 133 The position of the patient for the introduction of lipiodol into the segmental branches of the right lower lobe bronchus (III)



Fig 134 The final position of the patient after the introduction of lipiodol into the right bronchial tree

The technique of the introduction of lipiodol on the left side not quite the same as that on the right This is because of the differenc in the anatomy of the left and right bronchial trees Here too, separate filling of the upper and lower lobe bronchi offers certain advantages, for the same reasons as on the right side To fill the branches of the left upper lobe the patient must incline markedly



Fig 133 The initial position of the patient for the introduction of lipiodol into the left upper lobe bronchus and its segmental bronchus

to the left, the palm of his left hand resting on the floor As the left upper lobe bronchus does not branch off exactly laterally from the main bronchus, but antero-laterally, the position of the patient must be corresponding to this The right shoulder is therefore brought forward The head is held as much upright as possible The patient firmly pulls out his tongue with his right hand, breathing quietly and deeply Now 5 to 6 cc of lipiodol are slowly injected (fig 135) This quantity of lipiodol flows along the left wall of the trachea

into the left main bronchus and thus straight into the left upper lobe bronchus This takes about 10 seconds. In this position the branches of the lower (= lingular) division will become immediately well filled. Usually this deals exclusively with the lingular bronchi, but in some cases also with the anterior segmental bronchus, viz. if the latter branches off from the upper lobe bronchus together with the lingular division. This, however, *only occurs in a minority of cases* *To fill*



Fig 136 The position of the patient for the introduction of lipiodol into the lingular bronchi of the left upper lobe

the segmental branches of the upper division of the left bronchial tree the following procedure is employed The patient must bend his left elbow, thus assuming a markedly lateral Trendelenburg position for about 10 seconds Now the apical branch and also part of the anterior branch are filled The patient is then gradually brought into a more dorsal Trendelenburg posture, and the dorsal side-branch of the apico-posterior bronchus becomes filled As a result of the more axillary and ascending course of this branch as compared to the posterior bronchus of the right upper lobe, it is not necessary to make the patient assume a completely dorsal Trendelenburg posture. This

posterior branch can be accepted to be sufficiently filled after about 10 seconds The patient is then directed to resume his original sidewards inclining position, so that the anterior branch is further filled with the remaining lipiodol still present in the upper division of the upper lobe bronchus Eventually he is brought into a seated posture, inclining forwards and considerably to the left, and the lipiodol in the long lingular branches is thus given the opportunity of flowing on to the periphery (fig 136) After about 10 seconds more all bronchi of the upper lobe will usually be completely and well filled

To fill the left lower bronchi the patient has to assume an upright position, but at the same time he has to incline fairly markedly to the left Gradually the remaining 4 to 5 cc of lipiodol is injected, and this flows straight into the left lower lobe bronchus, filling the three large basal segmental branches To obtain a satisfactory filling of the apical bronchus, during the injection of the last cc of lipiodol the patient is gradually brought into a more backward reclining posture. This quantity of lipiodol will flow along the left posterior wall of the trachea, the left main bronchus and the lower lobe bronchus, and in this way the apical bronchus will also receive sufficient lipiodol The filling of all lower lobe bronchi takes about 20 seconds, so that for the performance of a complete lipiodol filling of the whole left bronchial tree a full minute is needed just as on the right side

The description of the introduction of the lipiodol filling for the right and left sides may appear to be a fairly intricate procedure This, however, is not the case The various consecutive positions are reasonably obvious if one visualizes the anatomy of the segmental branches of the bronchial tree The way in which the lipiodol is consecutively directed into the various bronchi is an excellent example of applied anatomical knowledge

The technique of introducing the lipiodol described above, has been employed in our clinic in a large series of patients The results have been very satisfactory, and almost invariably an excellent and equable filling of all branches is achieved With some patients, particularly those who are seriously ill or have been bedridden for a long time, it is impossible to introduce lipiodol in the usual way, with the patient seated on a bench. For these patients it is advisable to inject the lipiodol while they are lying on their side on a table In this way it is less tiring for them to endure the various postures, and it also gives good results Personally, we always prefer to perform the introduction of the lipiodol in the manner described if at all possible.

The technique, recommended by various American authors, of checking the progress of the filling on the roentgen-screen, is never used by us, except in the MÉTRAS technique which is discussed later on Fluoroscopy offers few advantages because without it the lipiodol can be directed into the segmental bronchi. Experience has taught us that the bronchograms obtained in our hospital, with our simple method, are certainly not inferior to those where the introduction of the lipiodol filling was fluoroscopically controlled, and it is our opinion that not infrequently they are even superior. The value of the technique described here, lies chiefly in the fact that good results are obtained by a simple method, with the use of very modest equipment available to anyone

The introduction of the lipiodol into young children. A separate description of the way in which the lipiodol filling is introduced into young children is necessary. With children over 8 to 9 years it can, as a rule, if one is patient, be performed in the usual way Under this age, however, this is rarely possible To perform bronchography in young children we always use the transglottic catheter method. The catheter, usually a semi-rigid one of a calibre of Ch 14, is introduced through the glottis into the trachea by means of direct laryngoscopy, without any anaesthesia. The laryngeal spatula of KILLIAN is very helpful The child is laid on a table on its back, and is firmly held by two assistants, a third assistant bending the head of the child markedly backwards With the help of a forehead lamp and the spatula (KILLIAN) it is easy to bring the glottis into view. By way of the spatula the catheter is inserted and pushed one or two inches into the trachea The spatula (KILLIAN) which consists of two separated parts, is quickly removed by a simple manipulation, the catheter remaining in the trachea As a rule, children struggle considerably, so it is very important to fix the catheter firmly and to work fast. The lipiodol which is warmed to body temperature, is quickly squirted through the catheter into the trachea, the child being brought consecutively into the left and the right lateral positions by the assistant who held the head during the introduction of the laryngeal spatula. In both of these positions a few cc of lipiodol are injected. The total quantity of lipiodol needed is small and depends on the childs' age. For very young children 6 to 8 cc is sufficient for both sides at one sitting, but for older children 10 to 15 cc is needed

With children it is not necessary to adopt consecutively the various positions described for adults to fill all the branches, because the

inspiration and the coughing during the filling result in adequate spreading of the lipiodol. Immediately after the injection of the lipiodol the catheter is quickly taken out, and the cough reflex caused by the remaining lipiodol is usually very slight. This is due to the fact that the lipiodol is warmed to body temperature before its introduction, thus reducing to a minimum the tendency to cough Because of the thinly liquid state at this temperature it will more easily spread in the slender bronchi of young children A unilateral introduction of lipiodol is sometimes possible in this way with quiet children, but often a bilateral filling results, despite all the efforts to limit it to one side only.

Careful attention should be paid to the correct position of the catheter in the trachea If it does not reach down far enough, it is apt to slip from the trachea into the pharynx when the child is struggling, and in that case all the lipiodol injected is swallowed and goes to the stomach If the catheter is pushed too far into the trachea, however, there is the possibility of its entering one of the main bronchi or even a lobar bronchus It should be borne in mind that the distances in children's bronchial trees are relatively small

As the lipiodol is injected under pressure, an incorrect position of the catheter may result in a, so-called, lipiodol infiltration, the X-ray picture of which, strongly resembles that of a pulmonary abscess, so that serious mistakes are possible

We have never seen any injurious results following lipiodol examination in children, when correctly performed This is probably chiefly due to the fact that, as no anaesthesia is used, all the lipiodol is expectorated soon.

The method of introducing the contrast oil, as described in the preceding pages, is used for all bronchographies It is striking that in a fairly large percentage of cases, viz in persons over 50 years of age, the segmental branches of the upper lobe bronchi can only be partly filled, whereas in younger persons, employing the same technique, this filling almost always appears to be satisfactory and complete. Even if the Trendelenburg position is maintained for a fairly long time, the patient breathing regularly and deeply, a better filling of the upper lobe bronchi is not usually obtained in older people. This fact can be accounted for. The spreading of lipiodol in the bronchi is chiefly effected — as was described in Chapter III — by gravitation and the suction force of inspiration. When the Trendelenburg position is assumed, gravitation will fill the upper lobe bronchi in the elderly, just as in younger persons It is reasonable to suppose,

therefore, that the suction force of inspiration is reduced. The upper lobes lie in that part of the chest where the normal respiratory excursions are the least In elderly people these excursions are considerably hampered by the stiffening of the costovertebral and other joints In addition, the older patients on whom a bronchographic examination is carried out, frequently belong to the category of chronic coughers They are usually to some extent afflicted with emphysema, so that the ribs are continuously in the inspiratory phase The patient compensates for this reduction in the respiratory movements of the chest wall by respiration of a more abdominal type. The result is that the upper lobes will not expand, as they would do in young people where the spaces in the upper parts of the chest fully expand This part of the chest is mostly affected by the increasing rigidity associated with advanced age In these cases the enlargement of the chest cage during inspiration is chiefly in the lower part of the thorax, so the lower lobes will expand relatively better than do the upper ones, and the same applies to the bronchi The inspiratory suction power is, therefore, less in the upper regions

This supposition is confirmed by observations made at lipiodol examinations Filling of the apical bronchi, in particular, is most difficult in elderly people The filling of the anterior and posterior segmental branches is usually successful, although not always complete In the spreading of lipiodol in the upper lobe branches of elderly people, gravitation probably plays the more important part. It is advisable, therefore, to warm the lipiodol to 100 degrees Fahrenheit for use in elderly people, so that it becomes thinly liquid, and will more easily penetrate into the apical branches.

The exact opposite applies to young people and children The upper part of the thorax expands very well on inspiration in young persons, because of its greater elasticity In the case of children it is not even necessary for them to assume the Trendelenburg position to obtain a satisfactory filling of the upper lobe areas The suction force of inspiration almost always achieves a good filling of all segmental bronchi, including the apical

One should, however, make a genuine effort to effect a complete filling of the apical upper lobe branches in the elderly, because this area often is the seat of disease. Bronchography is very important for diagnostic purposes and localization in this region in particular, as bronchoscopy has only a limited value for the upper lobe bronchi. According to our personal experience with older people, the best prospect of a good lipiodol filling of the upper areas is provided by

using lipiodol in a thinly liquid state, and by maintaining the Trendelenburg position for 2 to 3 minutes

The various roentgenograms It is generally agreed that it is most advisable to take the roentgenograms as soon as possible after the introduction of lipiodol In this way the best bronchograms are obtained. As a rule, alveolar filling has not taken place at this stage, or if it has, it is only to a slight extent, and, in consequence, the picture of the various bronchi is clear and sharp, and thus it can be properly examined

When affections exist which from the preceding medical and routine X-ray examinations appear to be localized on one side, one may content oneself with a unilateral lipiodol examination This is the case, for instance, when the presence of a foreign body, bronchostenosis with or without atelectasis of the corresponding part of the lung, an abscess, etc , are suspected The general condition may also sometimes necessitate a restriction of the investigation to unilateral bronchography For the unilateral contrast examination it is, as a rule, necessary to take at least two roentgen pictures, viz one dorso-ventral and one lateral The positions of the patient for these two views are exactly similar to those for the dorso-ventral and lateral pictures of the usual roentgenological survey When lipiodol is introduced into the side to be examined, one should make a definite effort to inject all the *lipiodol there If, however, in spite of all precautions* some of the lipiodol does go to the bronchi of the other side, it is often impossible to arrive at a satisfactory opinion about the lateral picture, because of the overlapping of the bronchi on either side In these cases an oblique projection must also be taken Its technique will be more extensively described in the discussion on bilateral bronchography Generally speaking, it is advisable when unilateral bronchography is performed, always to take an oblique view, because in addition to the reason referred to above, this bronchogram is particularly valuable for diagnostic purposes In our clinic a dorso-ventral, a lateral, and an oblique views are always taken when unilateral bronchography is done

The majority of patients considered for bronchography, however, consists of sufferers from processes which are localized bilaterally In these cases it is necessary, therefore, to carry out a complete bilateral lipiodol examination to obtain a survey of all bronchi This appears to be quite possible with the help of the oblique projections The characteristic pictures of the right and left bronchial trees in the

oblique projections have already been fully described in Chapter IV The question is whether it is possible to determine a constant average value for the most favourable angle at which the oblique projections must be taken, so that the roentgenograms obtained of the right and left bronchial trees are not only certain to possess the characteristics already described — including the diagnostic features —, but also to always keep the pictures of the right and left sides completely separate. This is actually possible By means of a long series of bronchographies, *we were able to state that the most favourable angle at which these* views can be taken, and almost without exception, comply with the requirements mentioned above, averages 25° with respect to the roentgen plate

As might be expected from theoretical considerations, the shape of the chest appears to play a certain part. In the cases of patients whose thoraces are circular in shape, the ratio of the dorso-ventral diameter to the lateral diameter is considerably greater than it is in those with flat chests, and in such patients also the dorso-ventral *dimension of the bronchial trees on either side is relatively larger* For this reason, the contrast pictures of the left and the right sides of a circular chest are more apt to overlap in the oblique views than is the case in a flat thorax A constant oblique projection angle of 25°, however, appears in practice to be satisfactorily serviceable for all shapes of the thorax At this angle the lipiodol pictures of the right and left bronchial trees seldom overlap, and all branches of the lobar bronchi are projected separately.

For the left anterior oblique view, in which the bronchial tree of the right lung in particular shows to full advantage, the patient is placed in front of the roentgen plate, turned to the right at an angle *of 25 degrees The left anterior part of the chest touches the roentgen*-plate, the right arm is stretched and raised horizontally sidewards, the left arm is rectangularly bent at the elbow-joint, and the left hand rests on the left hip For the right anterior oblique X-ray, which gives an excellent view of the bronchial tree of the left lung, the patient is also placed at an angle of 25 degrees — now turned to the left — between the roentgen tube and the plate. The right anterior part of the chest touches the roentgen plate, the left arm is raised horizontally sidewards, the right arm is rectangularly bent, and the right hand rests on the right hip

The oblique positions in front of the roentgen plate can be assumed *in two different ways*:

a. The patient stands at an angle of 25 degrees to the roentgen plate, wholly turned to the right or to the left.

b The patient assumes a position as used for taking a dorso-ventral bronchogram, and by means of a torsion of the spine of 25 degrees, brings his chest into the position wanted for the oblique view

Theoretically, there is the possibility that this might make some difference, but in practice this has not been found to be the case, because the torsion is almost exclusively effected in the lumbar part of the spine In both cases the roentgen pictures obtained are almost equally good, and it is, therefore, advisable to follow the method which *is easier for the patient, viz to place him in front of the plate with* his whole body turned 25 degrees to the right or to the left

Attention should be paid to the remarkable fact that when X-ray pictures are taken in the right and left anterior oblique positions, the bronchial tree chiefly under consideration is situated at some distance from the plate, whereas the bronchial tree of the other side, which is of far less importance, is very close to it This circumstance, however, has no appreciable deleterious effect on the clarity and sharpness of the picture, if good care is taken to place the patient as closely as possible to the roentgenplate This was clearly illustrated by the following experiment During the bilateral bronchographic examination of a few patients, the left and right anterior oblique views were first taken in the usual way Subsequently, the patient was turned round, so that he stood with his back to the roentgen-plate Now he was alternately turned 25 degrees to the right and to the left, and two oblique roentgenograms were taken in these positions A comparison of the views taken in the usual way and in the way described above, disclosed no important differences The distance between the roentgen tube and the plate may also be responsible for distortion and misleading pictures in the bronchogram The closer the tube is to the plate, the greater is the misrepresentation, particularly in the oblique positions The minimum distance between the tube and the plate should, therefore, always amount to at least one yard

In Chapter IV we already pointed out that the oblique views are in some respects inferior to the dorso-ventral and lateral projections, particularly in regard of the possibility of accurately localizing a shadow in a certain area of the lung For a good survey of the posterior branches of the upper lobes and the cardiac branch of the right lower lobe, they also sometimes leave something to be desired Consequently, we have concluded that the standpoint of some American authors, who think, that for a complete lipiodol examination of both lungs it is sufficient to introduce lipiodol simultaneously into both sides, and subsequently

the presence of bronchiectasis is suspected. As chest surgery is particularly successful in the treatment of bronchiectasis in children, it is necessary — in order to establish a correct indication for operation — to localize the process accurately by means of bronchography. It is evident that this will often be impossible with only a dorso-ventral view. For this reason, we have paid special attention to the results obtained when young children are X-rayed in the right and left oblique

to take two views only, in the right and left anterior oblique positions respectively, is not correct in the case of adults. We consider that the advantage sometimes offered by the dorso-ventral and, particularly, the lateral views for the diagnosis and the localization, is too great to omit these pictures. Bearing this in mind, the bronchographic examination of all cases where a complete bilateral examination is indicated, has for a considerable time been performed as follows first 10 cc of lipiodol is introduced unilaterally, on the side in which preceding physical and radiological examinations revealed the most important abnormalities. If the common examination did not give a definite indication, the lipiodol is first introduced into the right side, because here the certainty of obtaining a complete unilateral filling is greater than on the left. When this (unilateral) filling has been achieved, a dorso-ventral and a lateral views are quickly taken Immediately afterwards 10 cc of lipiodol is introduced into the other side, and another dorso-ventral view is taken (a bilateral one) followed by two views in the right and left anterior oblique positions respectively, at an angle of 25 degrees.

The complete series of bronchograms needed for the examination of the bronchial trees of both sides consists, therefore, of a series of 5 views, which must be taken in as quick a sequence as possible. Within a few minutes after the performance of the first lipiodol filling, the whole series of X-rays must be completed, as the picture of the first filling has by then begun to fade. Obviously, when the lipiodol examination of both sides is done in the way described here, a complete filling of all the bronchi on either side must be attempted. When there is something wrong with the first filling, the whole series of bronchograms will lose much of its diagnostic value The correctly performed complete bilateral lipiodol examination, however, supplies all diagnostic data available

In young children it is unfortunately impossible to carry out the bilateral examination in the way described above because — as has already been remarked — here it is very difficult to achieve a unilateral lipiodol filling. It is nearly always inevitable that a bilateral filling in one movement is effected, which makes it impossible to take a good lateral picture For this reason, until recently it has been customary to take a dorso-ventral view only, when performing bronchographic examination in young children Obviously, in this single X-ray the bronchi of the middle and lower lobes on the right, and of the lingula and lower lobe on the left, are often not projected separately In the majority of cases the contrast examination in children is done because

the presence of bronchiectasis is suspected As chest surgery is particularly successful in the treatment of bronchiectasis in children, it is necessary — in order to establish a correct indication for operation — to localize the process accurately by means of bronchography It is evident that this will often be impossible with only a dorso-ventral view For this reason, we have paid special attention to the results obtained when young children are X-rayed in the right and left oblique positions In these cases also, it appears possible to project the various branches of the right and left bronchial trees well apart Frequently, the films are even better than the ones taken in adults The most favourable average angle for taking the oblique projections in children appears to be almost the same as for adults viz about 25 degrees. Consequently, in children, too, it is possible to perform the complete bilateral lipiodol investigation at one sitting in such a way that nearly all segmental branches can be examined separately The technique described above is almost similar to the American method for adults, and has the same disadvantage, viz the impossibility of taking a lateral X-ray

One notable observation, when studying the oblique bronchograms of children, is that the X-rays of the right bronchial tree taken in the right anterior oblique position, and to a lesser degree the films of the left bronchial tree taken in the left anterior oblique position, are often very clear This is due to the fact that in children the spine scarcely interferes with the picture of the bronchial tree, because of the lesser calcium content of the bones

X-ray technique. We shall now describe in greater detail some points concerning the X-ray technique In the course of this chapter, the positions assumed by the patient for the various projections have already been discussed A specially constructed pair of wooden compasses is used to place patients at an angle of 25 for the oblique views Its shanks are about half a yard in length, and are connected by a joint with a clamping-screw A graduation scale permits the adjustment of the shanks in regard to each other, to any desired position between 0 and 90 degrees

If possible, the bronchograms are taken in a standing position Patients who have been bedridden for a long time, or who for other reasons are unable to stand, are X-rayed in a sitting position If this, too, is impossible, the bronchograms can be taken lying down The latter has its disadvantages, however, as it is difficult to assume the positions for the oblique views Very young children who are not able

to stand or sit, are X-rayed in a suspended position. They are suspended by their arms in the dorso-ventral, and left and right oblique positions (25 degrees) consecutively, in front of the roentgen-plate. If necessary, the legs are held by an assistant. In this way good pictures can be made, even with children of a very youthful age

The roentgenograms are taken on deep inspiration, the patient holding his breath for a moment. Often, particularly when the existence of bronchiectasis is suspected, pictures are also made on *deep expiration*. As a rule, hard X-ray pictures should be taken in bronchography, particularly, when it has been ascertained beforehand that a strong shadow caused by a tumour, infiltration, or liquid, exists.

When it is doubtful if a certain X-ray has been satisfactorily taken, e g. if the patient has moved, it is immediately retaken. The whole series of projections of the various positions is made as quickly as possible They are immediately developed and fixed, so that they can be viewed within a short time. Thus it is possible to see if the filling is adequate, and if this is not so, a part of the bronchial tree which is not sufficiently outlined, can be given an additional filling This is easily done by taking care that the part of the lung concerned is the lowest point when lipiodol is introduced

Finally, it is decided whether it is necessary or not to take a residual picture This is the case, e g when a lipiodol stop, bronchiectasis, etc. exist Depending on the seat of the anomaly in the bronchial tree, the residual picture is taken in a dorso-ventral or in one of the oblique positions, about 15 to 20 minutes after the introduction of the lipiodol. Pending the taking of the residual picture, the position of the patient during all this time should be such, that the area of the lung where the anomaly is present is the lowest In some cases it is important to take a, so -called, directed view of certain parts of the bronchial tree.

After treatment of the patient Particular attention should be paid to the after-treatment of the patient following the termination of the bronchographic examination This is very important in order to prevent complications. Immediately after taking the last roentgenogram, the lipiodol in the lung must be very quickly expectorated as completely as possible For this purpose the patient is, for a few minutes, directed to assume a position which is identical with QUINCKE's position for postural drainage of bronchiectatic cavities, and he is told to cough strongly all the time In this way, the greater part of the lipiodol is easily removed

Following the lipiodol investigation, the patient should, as a rule,

remain in bed for at least 24 hours If idiosyncrasy for iodine was present before the bronchography, the patient should spit out all the sputum expectorated during the first few hours after the examination, so as to prevent the appearance of idiosyncratic phenomena, caused by decomposition of lipiodol in the intestinal tract In view of the danger of choking and aspiration, as a result of the anaesthesia, no solid or liquid food should be taken for a few hours after the bronchography.

The Métras' technique.

The technique of the bronchographic examination in adults and children described in the preceding pages, is followed in our clinic in all cases We always prefer to perform the bronchography systematically i e to fill all branches of the bronchial tree consecutively with lipiodol and afterwards to study the series of bronchograms thus obtained

In the majority of cases this method actually supplies the desired data, but it cannot be denied that sometimes cases occur in which the standard method is inadequate As has been discussed in Chapter III, the lipiodol in the segmental and smaller bronchi is chiefly spread by the suction force acting in these bronchi during inspiration Gravitation plays an important part only in the spreading into the larger bronchi As a result of various pathological processes the inspiratory suction force in certain parts of the bronchial tree may be lessened or even completely inactive, so that these areas are not at all, or insufficiently filled with lipiodol With the standard technique one rarely succeeds in outlining a pulmonary abscess with lipiodol The segmental bronchus is usually blocked by secretion, and the bronchial wall is inflamed and, consequently, swollen The filling of the upper lobe bronchi in patients with old tuberculous processes is often only partially succesful Nevertheless, in many cases it may be very important to make visible those particular parts of the bronchial tree which are not at all, or only partly filled, due to diminished inspiratory suction force. This particularly applies to the parts of the bronchial tree that are, as a rule, rather insufficiently accessible for bronchoscopic examination, such as the apical and posterior segmental upper lobe bronchi on the right, the upper division of the upper lobe bronchus on the left with all its segmental side-branches, and — to a lesser extent — the apical segmental bronchi of both lower lobe bronchi In Chapter VI the value of a residual picture in these cases has already been discussed

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Following the lipiodol investigation, the patient should, as a rule,

parts the tip glides with a slight pressure along the mucous membrane of the bronchial wall, owing to the resilience of the curved end

On this fact the technique of the procedure is based, for the curved end of the sound will, because of its resilience, always tend to deviate sideways in a certain direction As long as the end moves in a straight part of the bronchial tree, this is of course impossible, but as soon as the tip of the probe reaches a ramification, it will tend to enter that bronchus of which the course coincides with the direction into which the point tends to deviate

So if one wants to introduce the catheter into a certain bronchus, one has to see that during this procedure the tip of the sound follows the bronchial wall in such a way that upon reaching the bronchus, it finds the lumen more or less automatically For example, if one wants to make the probe enter the right main bronchus one has to make sure that the tip glides along the right wall of the trachea If subsequently, one desires to find the right upper lobe bronchus the sound must be pushed on in the same direction In order to reach the right middle lobe bronchus it is necessary to turn the tip forward as soon as the sound has entered the right main bronchus from the trachea, so as to avoid the upper lobe bronchus The point then glides along the anterior wall of the main bronchus and the stem-bronchus without interruption, and it automatically finds the ostium of the middle lobe bronchus In the same way the apical branch of the lower lobe bronchus can be reached by making the tip follow the posterior wall of the main and stem-bronchi The models intended for probing the basal lower lobe bronchi on the left and on the right have a slightly curved end This is necessary, as an absolutely straight catheter would normally nearly always enter the right main bronchus Furthermore, the bend of the end makes the sound dirigible, so that the various ostea of the basal branches can be separately found by the point

A special curve is designed for the probes intended for sounding the segmental branches of the upper lobe bronchi on the right and on the left These models have their ends curved in two different planes, so MÉTRAS' principle is here double present One curve serves for directing the catheter into the upper lobe bronchus, the second bend makes it possible (by subsequently rotating the probe) to introduce the tip into the apical, anterior or posterior branches In the same way the lingular branches of the upper lobe bronchus on the left can be found

By choosing the correct model from MÉTRAS' series it is, therefore, possible to sound any segmental bronchus of the right and left sides

An excellent technique, devised by the Frenchman MÉTRAS from Marseilles, has made it possible to study segmental bronchi which are not filled, or only inadequately outlined by the usual method, by introducing a special sound, and subsequently injecting lipiodol through it. MÉTRAS designed a series of hollow rubber catheters, all of them about 20 inches long, and made from a kind of rubber con-

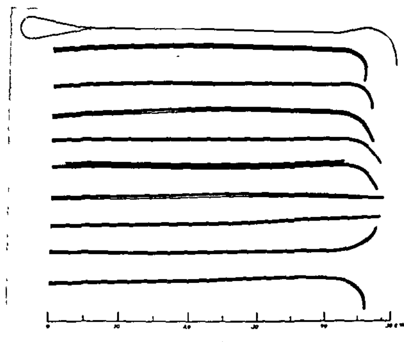


Fig 137 The various Métras' sounds

taining a fairly strong contrast medium for roentgen rays The tip of these probes is somewhat pointed, and contains a certain material which has a very strong contrast effect, so that it is clearly visible when fluoroscoping the thorax

The shapes and calibres of the sounds vary according to the bronchi to be probed In addition to a few straight models, MÉTRAS designed a number of special ones of which the ends are more or less strongly curved, and adopted as much as possible to the natural shape of the bronchi to be examined (fig 137). Notwithstanding this curve, it is very easy to push the catheters along the bronchial tree, in the straight

The technique of this procedure is fairly simple, but it is an absolute necessity to have, in addition to a good stereoscopic idea of the anatomy, a thorough knowledge of the direction of the branches of the bronchial tree in the various projection planes on fluoroscopy. The probes are guided under fluoroscopic view in different directions, and it is, therefore, imperative to be accurately acquainted with the places where the side-branches come off.

The introduction of the catheter into the trachea is very simple. The upper and lower air passages are anaesthetized in the usual way beforehand, by means of spraying and intratracheal injection of 2 cc of a 1 percent pantocain solution If later on, this anaesthesia does not prove to be quite sufficient, 1 cc of pantocain solution can be locally administered through the sound itself. The latter is introduced, with the help of a curved metal wire, below the level of the glottis Then the guide is withdrawn, and the sound is introduced further down This can be done equally well in a standing or in a lying down positions of the patient We usually prefer the lying down position, as it is, as a rule, more suited to the various aims for which MÉTRAS' method is used

The deeper introduction of the catheter is performed under fluoroscopic control by most authors. Some of them contend that this deeper introduction is also quite possible without fluoroscopy. They mark *the proximal end of the probe, so that they can always see in which* direction the distal tip is pointing, and thus they try blindly to enter the desired bronchus A great advantage of this method is that the *administration of an injurious dose of roentgen rays to the patient is* thus avoided Fluoroscopy must be performed with open shutters, and, therefore, when the sounding is carried out daily for a few weeks — as is the case *with some patients —, the effect of fluoroscopic* exposure may in the long run be injurious to the patient. The disadvantage of working without fluoroscopic control is considerable, and according to our experience, *this method is not too reliable However, if one repeatedly uses the* MÉTRAS' *technique, one* may actually blindly enter the various bronchi by the touch in a large percentage of cases *The personal training and experience* play an important part in this respect

In our clinic we generally blindly introduce MÉTRAS' probes, but afterwards, as a rule, *fluoroscopy is performed to check* if the sound has actually reached the bronchus in question. If necessary, a faulty position can be quickly corrected Fluoroscopy is usually carried out in a *dorso-ventral* position, *but for a few bronchi*, like the apical

lower lobe branches and the posterior upper lobe branches, lateral fluoroscopy is absolutely necessary Figures 138—141 show a few roentgenograms of patients where a MÉTRAS' sound was directed in position In *fig* 138 the catheter is situated *in the upper division* of the left upper lobe bronchus, and in fig 139 in its lower division.



Fig 138 Metras' sound in the upper division of the left upper lobe bronchus

In figs 140 and 141 it is seen in the anterior upper lobe bronchus, and in the apical lower lobe bronchus of the right side respectively

An important fact is that the introduction of the sound into segmental bronchi is most simply performed during inspiration, as the ostium is then wider For the same reason, it is also most easily pushed on towards the periphery during the same phase Due to the fact that the sounds are made of a soft kind of rubber and are introduced

with very little force, it is almost impossible for them to cause damage.

The possibilities offered by MÉTRAS' method are exclusively based on the principle that the probes can be introduced into almost any segmental bronchus, and fairly far towards the periphery. The bronchi which are usually not, or only partly accessible for inspection by means



Fig 139 Metras' sound in the lingular division of the left upper lobe bronchus

of bronchoscopy, can be easily reached With the help of MÉTRAS' sounds it is possible to remove secretion from any desired part of the bronchial tree The bacteriological and cytological examinations of this secretion may be of great diagnostic importance For therapeutic purposes, too, the removal of secretion by suction is often valuable, e g in the treatment of purulent bronchiectasis, pulmonary abscesses, postoperative atelectasis, etc. Furthermore, it is rather simple to inject

through the probes certain medicines for local treatment, e g penicillin, streptomycin, adrenalin, lipiodol, etc

MÉTRAS' method may also be useful in treatment of pulmonary suppurations, as for example the pulmonary abscess In not an inconsiderable number of cases the cure of a pulmonary abscess can,



Fig 140 Metras' sound in the anterior bronchus of the right upper lobe Lateral view

in addition to the usual therapy with antibiotics and sulfa-drugs, be effected by sounding the draining bronchus of the abscess, or even *the abscess itself, with a MÉTRAS' cathether, and daily emptying it by suction as much as possible, and subsequently injecting penicillin* dissolved in saline solution Our experience with this method is not very wide, but we have the impression that the sooner the local treatment of the pulmonary abscess by means of MÉTRAS' sounds is started, the better are the chances of complete recovery In more advanced

stages, too, this procedure is very valuable, as in most cases the abscess becomes considerably smaller and less active, thus improving the prospects of intended surgical therapy. Similarly, chronic purulent bronchiectasis may be treated with MÉTRAS' probes, the secretion can be locally removed by suction, and penicillin or other medicines are subsequently injected.



Fig 141 Métras' sound in the apical bronchus of the right lower lobe Lateral view

For bronchography MÉTRAS' technique is chiefly important when the standard method has supplied insufficient data. Usually, it is fairly simple to inject lipiodol by way of the catheter, even against a fair resistance, into those bronchi which could not be filled in the normal way. This can be done because the injection through the sound is performed under a certain pressure, which makes it easy to overcome resistance, caused by the presence of secretion or bronchostenosis. A complete blockage can also be demonstrated with great certainty in this way.

It is very advisable, when performing bronchography by means of the MÉTRAS' technique, to inject as little lipiodol as possible, 2 to 3 cc. is, as a rule, sufficient. If a greater quantity of lipiodol is injected, there is a chance that the surplus would spread into the alveoli under pressure, thus not only blurring the picture of the bronchi, but also



Fig. 142. Right bronchial tree. Dorso-ventral bronchogram. Upper lobe bronchus completely failed to fill.

giving the appearance of a "lac d'opacification" or sometimes even of a subpleural lipiodol infiltration. The injection of the lipiodol under pressure should, therefore, always be checked on the fluoroscopic screen, to ascertain if and when a sufficient filling of the area to be examined has been effected. The patient should preferably be directed to assume such a position that the area of the bronchial tree to be filled is the lowest part. The roentgenogram should also be taken in this position, if possible.

The X-ray pictures are immediately developed to see if the filling

is sufficient for diagnostic purposes, and if necessary more lipiodol can be introduced, and new and better views taken. The MÉTRAS' sound should, therefore, remain in its place until the examination is finished Only then is it removed, and the patient must expectorate the lipiodol in the usual way. It may be helpful to attempt beforehand



Fig 143 The same case as in fig 142 Metras' sound in the upper lobe bronchus Large cavity is now filled with lipiodol

to remove as much as possible of the lipiodol through the sound, by means of a suction apparatus

Figs 142—146 illustrate a few examples of cases where the MÉTRAS' technique was extremely useful. The first case was that of a man, aged 49, who had had a cough for over two years and expectorated large quantities of fetid sputum. Elsewhere, it had been roentgenologically ascertained that a cavity was present in the middle of the posterior area of the right lung. The patient was sent for examination in order to consider the possibility of surgical therapy We performed broncho-

graphy in the usual way (fig. 142), from which it appeared that the right upper lobe bronchus completely failed to fill. The middle lobe bronchi were normal, and in the lower lobe slight bronchiectasis could be seen in various places. The cavity, therefore, was not filled, and we suspected it to be localized in the upper lobe. The upper bronchus



Fig. 144. Métras filling of the bronchi of the right apical lower lobe segment. Lateral view. A small cavity, situated far towards the periphery, has been filled with lipiodol (arrow).

probably could not be filled with lipiodol on account of the presence of secretion. For this reason we performed a MÉTRAS' filling of this part of the bronchial tree, and we succeeded in demonstrating a large cavity (fig. 143) situated in the posterior segment.

The second case was that of a man of 63 years of age, who had been ill for 3 weeks and clinically had an atypical pneumonia. On the roentgenogram a medio-dorsal shadow was visible on the right side, and carcinoma was suspected. Elsewhere, bronchography had been carried out, and the whole right bronchial tree was well filled, except

for the area of the apical lower lobe bronchus. We then performed a MÉTRAS' filling of the bronchi of this particular segment, and we found a cavity situated fairly far towards the periphery (see fig. 144). As neither the subsequent examination of the bronchial curettage, nor the cytologic examination of the bronchial secretion gave any indications



Fig. 145. Right bronchial tree. Lateral view. The lower lobe bronchi are not well filled. Slight cylindrical dilatation of the middle lobe branches.

of the presence of a carcinoma, we assumed the presence of a pulmonary abscess. The patient daily received local treatment with penicillin by way of a MÉTRAS' sound, and he quickly recovered.

The third case was a woman, aged 21, who had expectorated fetid sputum for months, and had complained for three weeks of a pain in

the right chest On the roentgenogram a small cavity, containing liquid with a fluid level, was found on the right side of the mediastinum We performed bronchography, from which it appeared that the branches of the right upper lobe were normal, the middle lobe bronchi displaying slight cylindrical dilatations The lower lobe bronchi, however,

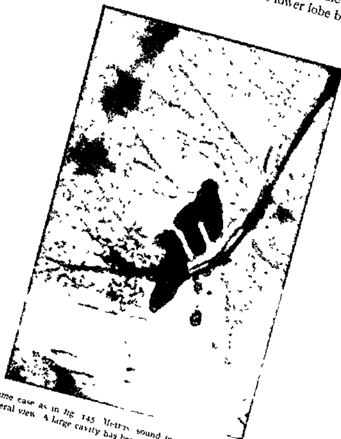


Fig 146 The same case as in fig 145 Metras sound in the apical lower lobe bronchus Lateral view A large cavity has been filled with lipiodol

were not well filled (fig 145) The apical segment, in particular, was very incompletely filled, and the basal segmental branches also revealed an unsatisfactory picture Except for the fact that it was evident that the cavity was situated in the lower lobe, no communication with the bronchial tree could be shown A repetition of the lipiodol examination

gave approximately the same results, and it proved impossible to localize the cavity more accurately in this way. During bronchoscopy, which was repeatedly carried out, a considerable quantity of secretion was always seen in the lower lobe bronchus and its segmental branches, the largest quantity, however, coming from the apical branch. For this reason we performed a MÉTRAS' filling of the area of this bronchus, and we now succeeded in introducing lipiodol into the cavity (fig 146) For a few weeks we daily injected penicillin into the cavity through the MÉTRAS' sound, after which the productive cough had almost disappeared On the roentgenogram the cavity was seen to have become smaller, and the fluid level was no longer visible She was then referred to the surgical department for further treatment The right middle and lower lobes were removed, and the latter contained a large pulmonary cyst The patient completely recovered.

REFERENCES

ANATOMY AND PHYSIOLOGY OF THE BRONCHIAL TREE

ADAMS, R, DAVENPORT, L F, Journ Am med ass 118, 111, 1942
AEBY, CHR, Der Bronchialbaum der Saugethiere und des Menschen (1880)
— Arch Anat u Physiol (1882)

BAARSMA, P R, Collaterale ventilatie Dissert Groningen (1943)
BAARSMA, P R DIRKEN, M N J, Ned tijdschr v gen 86, 2068 (1942)
BAARSMA, P R DIRKEN, M N J HUIZINGA, E Ned tijdschr v gen 95, 1852 (1947)
BENDER, K W, Zeitschr Anat u Entw 75, (1925)
BRAUS, H, Anatomie des Menschen (1924)
BRUNINGS, W, ALBRECHT, W Direkte Endoskopie der Luft- und Speisewege (1915)
BRUNINGS W, Die direkte Laryngoskopie, Bronchoskopie und Oesophagoskopie (1910)
BREMER, J L, Am journ anat 3, 67 (1904)
BROCK R C, Guy's hospital reports 91, 140 (1942) 93, 90 (1944)
BROMAN, J Die Entwicklung des Menschen vor der Geburt (1927)

CHURCHILL, E BELSEY R, Ann surg 109, 481 (1939)
COLNIHAN, Thorax 93 (1946)

DÉVE, F, Bull et mém soc anat Paris 74, 489 (1899)
— Bull et mém soc anat Paris 75, 341 (1900)
— Bull et mém soc anat de Paris 270 (1903)
DWIGHT DAVIS J, Arch oto-rhino laryngol 9, 404 (1929)

EKEHORN, G, Zeitschr Anat u Entw 62, 271 (1921)
ELLIS, M, The journ of physiol 87, 298 (1936)
ERWIN G S, Lancet 1, 1236 (1936)
EWART, W, The bronchi and pulmonary blood vessels London 1889 (Ref Neil Brit med journ 1, 495 (1939)

FELIX, W, In F Sauerbruch Chirurgie der Brustorgane (1920)
FISCHEL A Lehrbuch der Entwicklung des Menschen (1929)
FLEISCHNER, F Fortschr Geb Rontgenstr 53, 607 (1936)
FLINT, J M Am journ anat 6, 1 (1907)
FORSTER-CARTER A F, Brit journ tuberc 36, 19 (1942)
— Recent medical science (1940—1945)

GILROY GLASS, E J Brit med journ 2, 1950 (1939)
GRANDGIRARD R HEIM DE BALSAC R, Presse méd 45, 444 (1937)
GUISEZ J, Trachéobronchoscopie et oesophagoscopie (1905)

HAGENS, E W, Ann otol, rhinol and laryngol. 52, 912 (1943).
HASSE, C, Arch Anat u Physiol (1892)
D'HARDIVILLER, Bibliogr anat, Sept, Oct 1896, Janv, Fevr, 1897
— Compt rend soc biol 19 Déc 1896, 4 et 11 Déc 1897.
— Compt rend acad sciences (1897).
HEISS, B R, Anat Anz 41, 62 (1912)
— Ergebn Anat u Entw 24, 244 (1923)
HERRNHEISER, G, Fortschr Geb Rontgenstr 53, 251 (1936)
HESSER, C, Anat Hefte 29, 88 (1905)
HILBER, H, Morphol Jahrb 71, 181 (1932)
HIS, W, Arch Anat u Physiol (1887)
HOVELACQUE, P, MONOD, O, EVRARD, H, Anatomie médico-chirurgicale (1937)
HUDSON, W A, JARRE H A, Brit journ radiol 2, 523 (1929)
HUIZINGA, E, Ned tijdsch v gen 77, 3351 (1933)
HUIZINGA, E, BEHR, E, Ned tijdschr v gen 82, 4271 (1938).
— Ned tijdschr v gen 82, 3209 (1938)
— Ned tijdschr v gen 83, 3489 (1939)
HUIZINGA, E, POTHOVEN, W J, Ned tijdschr v gen 86, 237 (1942)
HUNTINGTON, G S, Am journ anat 27, 99, (1920)
— Ann N Y acad sci 11, 127 (1898)
— Anat rec 17, 165 (1920)
HUNTINGTON, G S, in NEAL, H V, and RAND, H W, Comparative anatomy. Blakiston's Son and Co, Philadelphia 1936

JACKSON, CHEV, Tracheobronchoscopy, esophagoscopy and gastroscopy (1907)
JACKSON, CHEV, JACKSON, CHEV L, Diseases of the nose, throat and ear (1945).
JACKSON, CHEV L, HUBER, J F, Diseases of the chest (1943)

KEYSER, S, Ned tijdschr v gen 81, 6084 (1937)
KRAMER, R, GLASS, A, Ann otol, rhinol and laryngol 41, 1210 (1932)

LEBOUCQ, H, Zool Anz 4, 238 (1881)
LEVITIN, J, BRUNN, H, Arch int med 57, 649 (1936)
LUCIEN, M, WEBER, P, Arch anat, hist et embr 21, 109 (1936)

MACKLIN, C C, Am rev tuberc 25, 393 (1932)
MANN, H, Lehrbuch der Tracheo-Bronchoskopie (1914)
MARCUS, H, Morphol Jahrb 58, 100 (1927), 59, 297 en 561 (1928)
— *Handbuch der vergleichenden Anatomie der* Wirbeltiere, III, 937.
MATTEI, C, TRISTANI, M, BARBE, A, Presse méd 47, 638 (1946)
MILLER, W S, The lung (1937)
MITCHELL, H E, Ann otol, rhinol and laryngol 55, 609 (1946)
MOOLTEN, S E, Arch path 20, 77 (1935)
MOSER, F, Arch mikr Anat u Entw mech 60, (1902).

NARATH, A, Der Bronchialbaum der Säugetiere und des Menschen (1901).
NEERGAARD, K VON, Zeitschr exp Med 66, 373 (1929).
NEIL, J H, GILMOUR, W, GWYNNE, F J, MAIN, W, FAIRCLOUGH, W. A., Ann otol, rhinol and laryngol 46, 338 (1937)

NEIL, J H; GILMOUR, W, GWYNNE, F J, Brit med journ 1, 495 (1939)
NEIL, J H, GILMOUR, W, Arch of otolar 50, 9 (1949)
NELSON, H P, Brit med journ 2, 251 (1934)
— Journ anat 66, 228 (1932)

PIERRET, R, COLLOUMA, P, BRETON, A, DEVOS, L, Ann d'anat path 15, 233 (1938)
PIERSON, W M, Ann otol, rhinol and laryngol 55, 604 (1946)
POLICARD, A, GALY, P Les Bronches Paris 1945

RAP, A A, Over de anatomie van de bronchiaalboom en de verdeling der longsegmenten, Groningen 1947
ROHRER, F, Pflügers Arch 162, 225 (1915)

SCHAFFNER, G, Arch path Anat usw 1, 152 (1898)
SCANNELL, J G, Journ thor surg 16 (1947)
— Journ thor surg 17 (1948)

WEBER, M, Zool Anz 4, 88 (1881)
WEINGAERTNER, M, Physiologische und topographische Studien am Tracheo bronchialbaum des lebenden Menschen (1919)
— Arch Laryngol Rhinol 32, 1 (1920)
WIEDERSHEIM, R, Vergleichende Anatomie der Wirbeltiere Jena 1909
WILLACH, P, Beitrag zur Entwicklung der Lunge bei Saugetieren (1888)

ZUMSTEIN, J, Sitz Ber Ges Beford gesammt Naturwiss Marburg 1889

BRONCHOGRAPHY

ADAMS, R, DAVENPORT, L F Journ Am med ass 118, 111 (1942)
AMBERSON, J, BURNS J, LEOD RIGGENS, H Mc, Am journ roentg 30, 727 (1933)
ANSPACH, W E, Am journ dis childr 47, 1011 (1934)
ARCHIBALD, E W, BROWN, A L, Journ Am med ass 88, 1310 (1927)
ARMAND-DELILLE, P F, DUHAMEL, G, MARTY, P, Presse méd 32, 421 (1924)
ARMAND-DELILLE, P F, LEUNDA, J, Presse méd 38, 378 (1930)
ARMAND-DELILLE, P F, LEVY, R J, JULIEN, J M, Rev franç pédiatr 1, 125 (1925)
ARMAND-DELILLE P F, MONCRIEFF, A, Brit med journ 378 (1930, I)
ALMONT, P, Bull et mém soc radiol méd France 13, 82 (1926)

BAATZ, K, Munch med Wochenschr 76, 1644 1929)
BAKER, A H L, Brit journ anaesth 17, 112 (1941)
BAKER, D C, Laryngoscope 46, 873, (1936)
BALLON, D H, Arch otolaryngol 3, 403 (1926)
BALLON, D H., BALLON H C, Act oto-laryngol 11, 580 (1927)
— Arch surg 14, 184 (1927)
— Journ laryng and otol 44, 153 (1929)

BALLON, H C, Frankf Zeitschr Path 36, 207 (1928)
BALLON, H C, SINGER, J J, GRAHAM, E A, Journ thorac surg 1, 154; 296, 397, 502 (1932)
BASCH, F P, HOLINGER, P H, PONCHER, H G, Am journ. dis. childr. 62, 981 (1941)
BASS, E, Med Welt, 944 (1939)
BENDOVE, R A, GERSHWIN, B S, Arch int med 54, 131 (1934)
— Am journ roentg 31, 323 (1934)
BERGSMA, D, Dissert Groningen 1947
BERNOU A, CARDIS, F, Beitr Klin Tuberk 67, 492 (1927)
BESANÇON, F, AZOULAY, R; Bull et mém soc méd hôp Paris 40, 226 (1924)
— Paris méd 15, 60 (1925)
BESANÇON, F, AZOULAY, R, MARTIN, A, Presse méd 43, 1537 (1935).
BEUTEL, A, Fortschr Geb Rontgenstr 48, 198 (1933)
— Rontgenpraxis 7, 157 (1935)
— Med Klin 52, 138 (1939)
BEUTEL, A, STRNAD, FR, Fortschr Geb Röntgenstr 55, 118 (1937)
BLAISDELL, I H, Laryngoscope 58, 288 (1948)
BLANCO, P P, CAPURRO, F G, Bronchoscopie etc 214 (1935)
BLOCH, R G, Am journ roentg 27, 847 (1932)
BONNAMOUR BADOLLE Journ radiol et d'électrol 10, 392 (1926)
— Presse méd 6 Févr 1929
BONNAMOUR, BADOLLE, GAILLARD, Journ radiol et d'électrol 10, 390 (1926)
BOUCHACOURT, L, Bull et mém soc radiol méd France 13, 188 (1926)
BRANDEN, J VAN DEN, GRUHBERG, M, Bull soc Belg otol etc. 1, 111 (1936)
BRUIN, M DE, Ned tijdschr v gen 77, 5345 (1933)
BRUNECKE, K, Beitr Klin Tuberk 62, 621 (1926)
BURRELL, L S T, Brit journ radiol 1, 19 (1928)
BURRELL L S T, MEVILLE, S, Lancet 209, 278 (1925)

CHAUFFARD, DEVIC ET SAVY Rev de méd (1910)
CLERF, L H Laryngoscope 44, 571 (1934)
COTTENOT P Bull et mém soc radiol méd France 14, 125 (1926)
COOPE, R, Diseases of the chest E and S Livingstone, Edinburg 1945
CORDIER, V, MOUNIER-KUHN, P L, Traitement des suppurations pulmonaires Masson et Cie, Paris 1938
COURTOIS, R, Bruxell méd 9, 709 (1929)
COYON, A, MARTY, P, AIMÉ, P, Bull et mém soc méd hôp Paris 41, 385 (1925)
CURSCHMANN, W, Beitr Klin Tuberk 72, 713 (1929)

DAVIDSON F W, Ann otol, rhinol and laryngol 53, 849 (1944)
DEBRÉ, R, GILBRIN E, Presse méd 1115 (1934)
DEBRÉ R Presse med, nr 19 (1936)
DIAMOND, S, LOON, E VAN, Journ Am med ass 118, 771 (1942)
DONALDSON J K Surgical disorders of the chest London 1944
DUHEM P, Paris méd 19, 110 (1929)

EGAN, E, Fortschr Geb Rontgenstr. 33, 199 (1925)

EGLES, J, Ref Zentralbl Hals-Nasen-Ohrenheilk 27, 474 (1937)
ELLIS, Arch dis childh 8, 25 (1933)
ERLANDSSON, S, Beitr Klin Tuberk 76, 105 (1930)
ERWIN, G S, Lancet 1236 (1936, I)
EVANS, W. A, GALINSKY, L J, Am journ roentg 51, 537 (1944)
FARINAS P L, Fortschr Geb Rontgenstr 53, 17 (1936)
— Am journ roentg 40, 180 (1938)
FARRELL, J T, Journ Am med ass 106, 92 (1936)
FINDLAY, L, Arch dis childh 10, 61 (1935)
FISCHER, F K, Schweiz med Wochenschr 78, 1025 (1948)
FISCHER, F K, MULLY, K, Schweiz med Wochenschr 78, 1033 (1948)
FLEISCHNER, F G, Am journ roentg 46, 166 (1941)
FORESTIER, J, LEROUX, L Journ radiol et d électrol 7, 351 (1923)
— Radiology 24, 743 (1935)

GALLWOSZUS, H, Dissert Konigsberg 1936
— Deutsch med Wochenschr 1290 (1937)
GARCIA-OTERO, J, BARCIA P A VOLONTERIO M Journ radiol et d électrol 19 441 (1935), 20, 388 (1936)
GENTILLE, A, Valsalva 13, 450 (1937)
GILLROY GLASS, E J, Brit med journ 950 (1939 II)
GILSE, P H G VAN, Act oto-laryngol 11, 603 (1927)
— Arch Hals-Nasen-Ohrenheilk 121, 81 (1929)
GOLDMAN, A, MAYER, R, Ann surg 106, 976 (1937)
GOODALE R L, Ann otol, rhinol and laryngol 47, 347 (1938)
GOODYEAR, H M, Laryngoscope 45, 511 (1935)
GRADY, H W Am journ roentg 15, 65 (1926)
GREEN, E, CALLOHAN, F F, GARDINER D C Am rev tuberc 19, 934 (1929)
GRIER, G S, Arch int med 73, 444 (1944)
GUNTHER, M, Deutsch med Wochenschr 1675 (1935)

HARMER, L, Wien med Wochenschr 1037 (1934, II)
HASLINGER, F, Monatschr Ohrenheilk 63, 357 560, 617, 782 (1929)
— Wien med Wochenschr 1571 1620 (1931 II)
HIGGLET, G, Arch méd chir de l'app resp 10 (1935)
HICKEY, P M, FURSTENBERG, A C Am journ roentg 15, 227 (1926)
HODGE, G E, Arch otolaryngol 22, 537 (1935)
HOLINGER, P H, Ann otol, rhinol and laryngol 47, 1070 (1938)
— Journ Am med ass 117, 675 (1941)
— Laryngoscope 52, 317 (1942)
HUIZINGA, E, Act oto-laryngol 16, 141 (1931)
— Zeitschr Hals-Nasen-Ohrenheilk 37, 87 (1934) 39, 521 (1936)
— Ned tijdschr v gen 79, 151, (1935), 81, 576 (1937), 83, 2331 5149 (1939), 85, 1726 (1941), 86, 118 (1942)
— Rev laryngol otol et rhinol Févr 1936
— Act radiol 21, 75, 392 (1940)
— Geneesk gids 25, 81 (1947)
HUIZINGA, E, KEYSER S, POLAK DANIELS, L, Ned tijdschr v gen 77, 3969 (1939)

Iglauer, S, Journ Am med ass **86**, *1879 (1926)*.
Iglauer, S, Kuhn, H, Journ Am med ass **90**, *1278 (1928)*

Jackson, Ch, Am journ. roentg **5**, 454 (1918)
— Journ Am med ass **79**, 1939 (1922)
Jackson, Chevalier L, Bonnier, M, Ann otol., rhinol. and laryngol. **46**, 771 (1937)
Jackson, Ch, Jackson Chevalier L, Diseases of the nose, throat and ear. Philadelphia 1945
Jacobaeus, H C, Westermark, N., Act radiol **11**, 545 (1930)
Jacoby, N M, Keats, G, Lancet *191 (1938, II)*
Jacod, M, Ann d'oto-laryngol *789 (1936)*.
Jennings, G H, Brit med journ **2**, *963 (1937)*
Jones, D H, Ann otol, rhinol and laryngol **46**, 749 (1937)

Kartagener, M, Beitr. Klin Tuberk **83**, *73*, 489 (1933)
— Ergebn inn Med **44**, *378 (1935)*
Kartagener, M, Horlacher, A, Schweiz med Wochenschr *782 (1935, II)*
Kartagener, M, Ulrich, K, Beitr Klin Tuberk **86**, 349 *(1935)*
Kautsky, A, Fortschr Geb Rontgenstr **54**, 219 (1936), **56**, 24 (1937), **57**, 168 (1938)
Kerley, P, Brit journ. radiol **7**, *531 (1934)*.
King, S D, Journ thorac surg **6**, *666 (1937)*
Knipping, H W, Ponndorf, W, Beitr Klin Tuberk **63**, 329 (1926)
Kopstein, G, Fortschr Geb Rontgenstr **48**, 145 *(1933)*
Kovats, F, Ref Zentralbl Hals-Nasen-Ohrenheilk **7**, *652, 774 (1925)*

Landau, W, Klin Wochenschr **4**, 1861 (1925).
Lasagna, F, Zeitschr Hals-Nasen-Ohrenheilk **40**, *603 (1937)*
Leegaard, T., Dissert Oslo *1944*
Leemda, Curran, Arch méd enf **33**, 347 (1930)
Lenk, R, Haslinger, F, Presser, K, Fortschr Geb Rontgenstr **34**, 117 (1925)
Leon-Kindberg, M, Konrilsky, R, Bull et mém soc méd hôp Paris **42**, 1812 (1927)
Lesne, Lemaricy, Bull soc pédiatr Paris **23**, 640 (1925)
Lichtwitz, O, Wien chir Wochenschr **39**, *5, 133 (1926)*
Lickint, F; Hippe, Med Klin *937 (1934, II)*.
Loffler, W, Ref Zentralbl Hals-Nasen-Ohrenheilk **28**, 258 (1937).
Lorey, A, Fortschr Geb Rontgenstr **34**, 127 (1926), **36**, 29 (1927)
— Deutsch med Wochenschr **55**, 526 (1929, I)
Lynah, H L., Stewart, W H, Am journ roentg **8**, 49 (1921)

Métras, H, Presse méd **17**, 198 (1947)
— L'arbre bronchique Vigot Frères Paris 1948
Moore, A B, Marquis, W J, Am journ roentg **13**, 527 (1925)
Morel, Kahn, Bull et mém soc radiol méd France **22**, 251 (1934).
Morlock, Pinchin, Brit med journ **1**, 12 (1930)
Mosher, H P, Laryngoscope **37**, 138 (1927).

Mounier-Kuhn, P, Lévy, A, Rev laryngol, otol et rhinol 52, 427 (1931)
Murphy, J E, Am journ roentg 31, 301 (1934)
Myers, D W, Blades, B, Am journ roentg 44, 530 (1940)

Neuhof, H, Am journ roentg 31, 287 (1934)

Ochsner, A, Ref Zentralbl Hals-Nasen-Ohrenheilk 11, 174 (1928)
— Radiology 11, 412 (1928)
— Journ Am med ass 93, 188 (1939)
Orso, L, Monatschr Ohrenheilk 77, 279 (1943)
Ostrowsky, F, Bross, W, Ref Zentralbl Hals Nasen-Ohrenheilk 28, 233 (1937)

Parade, G W, Med Klin 30, 1483 (1934)
Pearson, H E S, Thornton H L, Brit journ radiol 12, 229 (1939)
Peirce, C B, Stocking, B W, Am journ roentg 38, 245 (1937)
Peirce, C B Am journ roentg 44, 846 (1940)
Pohl, R, Fortschr Geb Rontgenstr 56, 13 (1937)
Popovic, L, Fortschr Geb Rontgenstr 40, 621 (1929)
— Act oto laryngol Slav 4, 173 (1933)
Potter, B P Am journ roentg 31, 308 (1934)
Pritchard S, Whyte B, Gordon, J K M, Journ Am med ass 86, 1119 (1926)
— Radiology 8, 104 (1927)

Rad A, Wien klin Wochenschr 39, 1011 (1926)
Reichle, H S, Arch of path 25, 811 (1938)
Reinberg, S, Fortschr Geb Rontgenstr 33, 661 (1925)
Reinberg, S, Kaplan, J Ref Zentralbl Hals Nasen Ohrenheilk 8, 399 (1926)
Reverchon L, Worms, G, Rev laryngol otol et rhinol 46, 189 (1925)
Reverdin A Presse méd 34, 1027 (1926)
Reynolds, G S Mc, Shelton F W, Ann otol rhinol and laryngol 54, 114 (1945)
Rist, E, Jacob, P, Soulas, A, Bull et mém soc méd hop Paris 42, 1082 (1926)
— Ann de méd 724 (1927)
Rist, Jacob, Troche Ann de méd (Fevrier 1917)
Robin, P A, Am journ roentg 51, 724 (1944)
Rocher, H L, Guérin, R, Arch d'électr méd 12 (1929)
Rosenthal, G, Paris méd 18, 134 (1928)
Rudman, I E, Am rev tuberc 39, 329 (1939)

Salkin, D, Cadden, A V, Mc Indue R B Am rev tuberc 34, 649 (1936)
Sante, L R, Am journ roentg 32, 763 (1934)
Sauerbruch T, Arch klin Chir 148, 721 (1927)
Scadding, J G Brit med journ, 1147 (1934 II)
Schilling, K, Fortschr Geb Rontgenstr 36, 301 (1927)
Schneider, L, Segal, J, Am rev tuberc 35, 590 (1937)
Secousse, H, Retrouvey, H Rev laryngol, otol et rhinol 51, 721 (1930)

SERGENT EM Paris med 17, 421, 428 (1927), 40, 273 (1932)
SERGENT BORDET E Bull soc méd de Paris 743 (1927)
SERGENT EM BORDET F DURAND, H; COUTREUX, J, Exploration radiologique de l'appareil respiratoire. Masson et Cie. Paris 1931
SERGENT EM COTTENOT P Presse méd 37, 481 (1929)
SGALITZER F Arch klin Chir 158, 197 (1925)
SICARD J A FORESTIER J Diagnostic et thérapeutique par le lipiodol Masson et Cie Paris 1928
SIMON G BLUMENBERG W Beitr Klin Tuberk 80, 234 (1932)
SINGER J J Journ Am med ass 87, 1298 (1926)
— Arch surg 19, 1571 (1929)
SINGER J J GRAHAM E A Am journ roentg 15, 54 (1926)
SINGER S Ergebn inn Med 35, 429 (1929)
SMELT G J, Dubbelzijdige bronchographie Groningen 1947
SMYTH CAMPBELL D LE ROY A S, Ann otol rhinol and laryngol 36, 1134 (1927)
SPARKS J V Brit journ radiol 1, 111 (1928)
— Brit journ radiol 4, 30 (1931)
STEINMEYER KATHE Beitr Klin Tuberk 64, 275 (1926)
STRNAD F Fortschr Geb Rontgenstr 58, 135 (1938)
STRNAD F BEUTEL A Rontgenpraxis 9, 484 (1937)

TANNENBERG J PINNER, M Journ thorac surg 11, 571 (1942)
TEALL C G Brit journ radiol 10, 637 (1937)
TENDELOO N PH Studien uber die Entstehung und den Verlauf der Lungenkrankheiten Munchen 1931
TOPSIE et SOREL Bull soc méd de Paris 1039 (1927)
TUCKER G Am journ roentg 15, 419 (1926)
— Ann otol, rhinol and laryngol 37, 569 (1928)

USPENSKY A HELFON, A, Fortschr Geb Rontgenstr 44, 635 (1931)

VALLEBONA A Ref Zentralbl Hals-Nasen-Ohrenheilk 28, 9 (1937)

WAMSTEKER H Dissert Leiden 1932
WEINBERG J A, Arch surg 24, 545 (1933)
WESSELY, E, Wien med Wochenschr 836 (1938)
WESTERMARK N, Act radiol 11, 113 (1930)
WIERIG, A, Fortschr Geb Rontgenstr 35, 787 (1927)
WIESE, O, Die Bronchiektasie im Kindesalter Monographie Verlag Springer, Berlin 1927
— Zeitschr Kinderheilk 53, 36 (1932)
— Kinderartzl Prax 6, 59 211 (1935)
WIESE, O, HINDERSIN L Zeitschr Kinderheilk 54, 657 (1933)
WISHART D E S, Ann of otol 56, 404 (1947)
WOLFSON, L E, GOLDEN, L A, Ann otol, r[illegible] laryngol 42, [illegible] (1933)
WYATT, G M, Am journ roentg 47, 864 [illegible]

ZAVOD W A, Am [illegible] 55, 356 [illegible]